EARTH

CAVENDISH

AIR

CHEMISTRY AS APPLIED TO THE ARTS & MANUFACTURES

DALTON

DAVY

FIRE

FARADAY

WATER

CHEMISTRY,

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED TO THE

ARTS AND MANUFACTURES.

BY

WRITERS OF EMINENCE.

ESTABLISHED 1803

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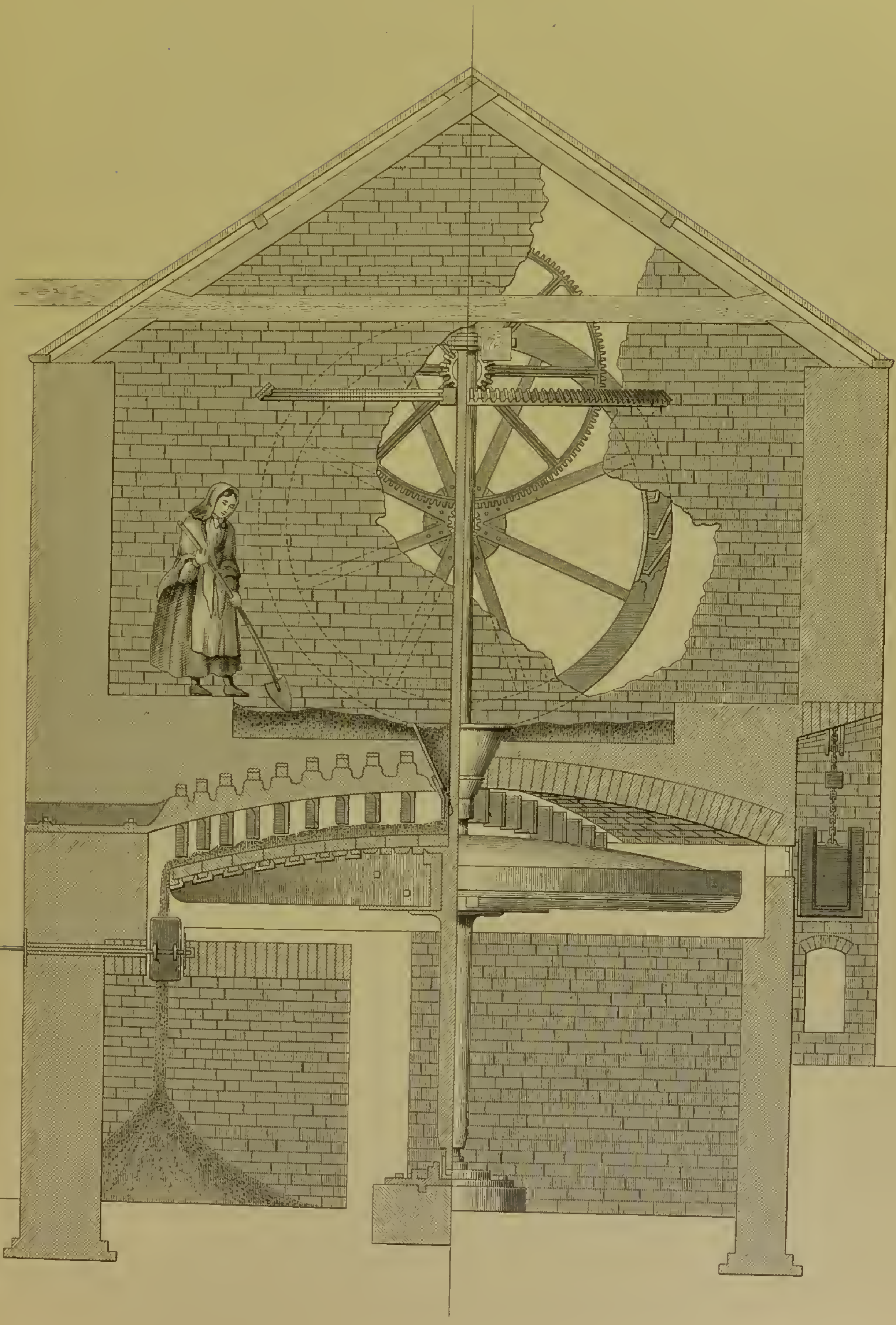
BRUNTON'S CALCINER



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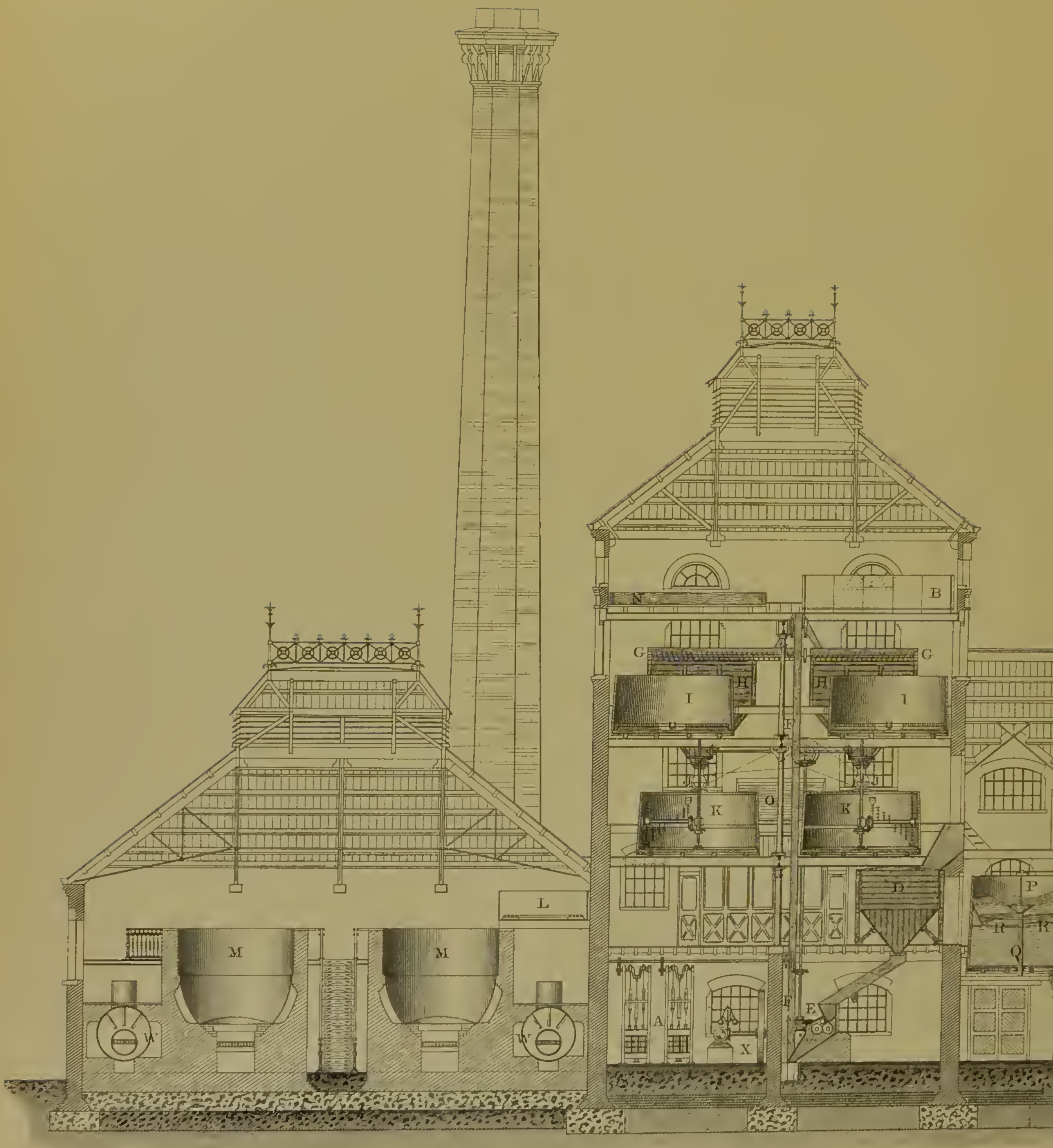
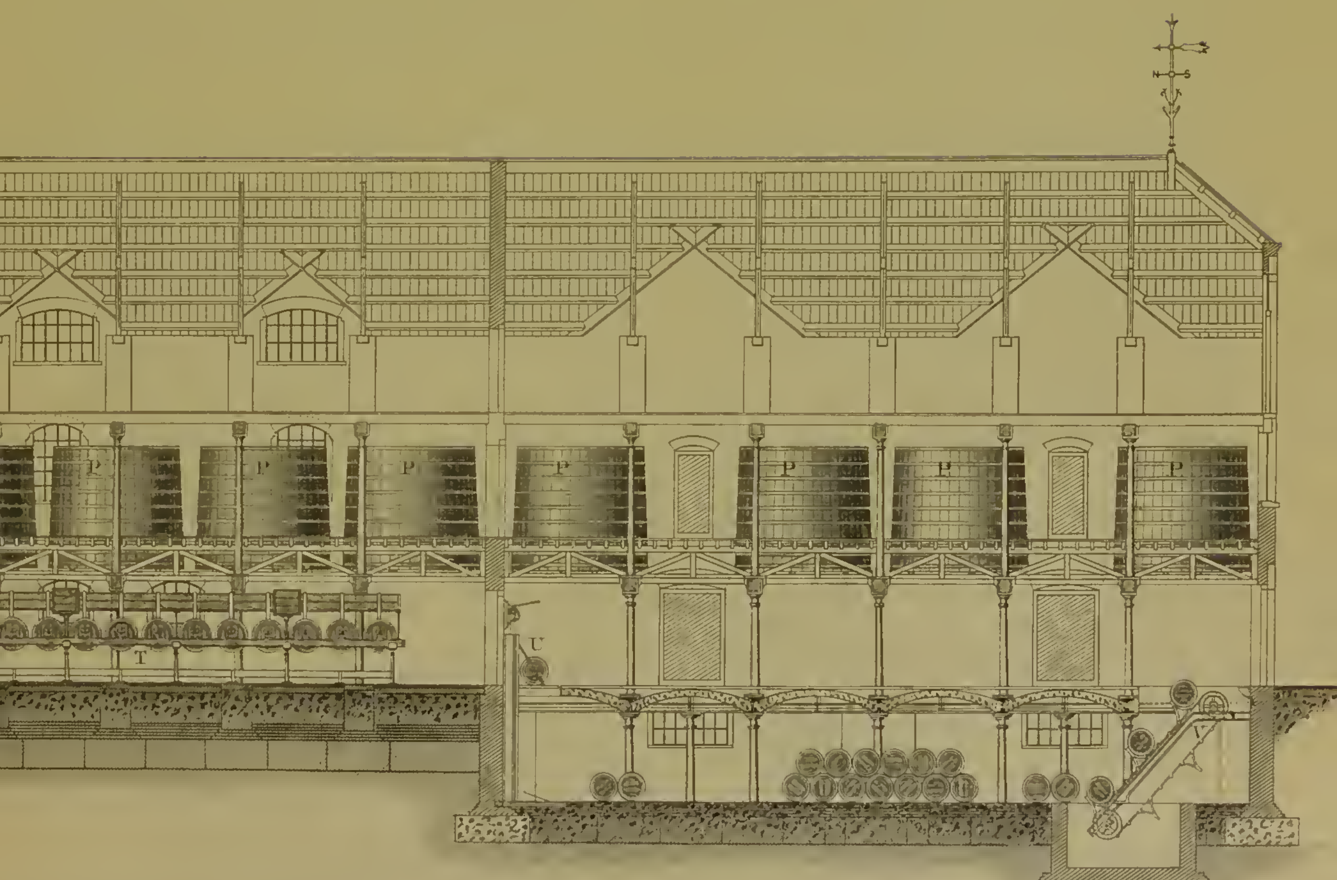


A *Pumps* B *Cold Liquor Back.* C *Malt Store* D *Malt Hopper.* E *Malt Rolls.* F *Elevator* G *Malt Screws.* H
O *Refrigerator* P *Fermenting Tuns.* Q *Skimming Apparatus.* R *Attemperator* S *Tun Room.* T *Union Clea*

B E E R.

PLATE I.

ON OF BREWERY



I Hot Liquor Backs J Steel's Mashing Machines K Mash Tuns L Under Back M Wort Coppers N Cooler.
U Cask Lowering Machine V Cask Raising Machine. W Steam Boilers X Steam Engine.

CHLORINE.

WELDON'S CHLORINE STILL.

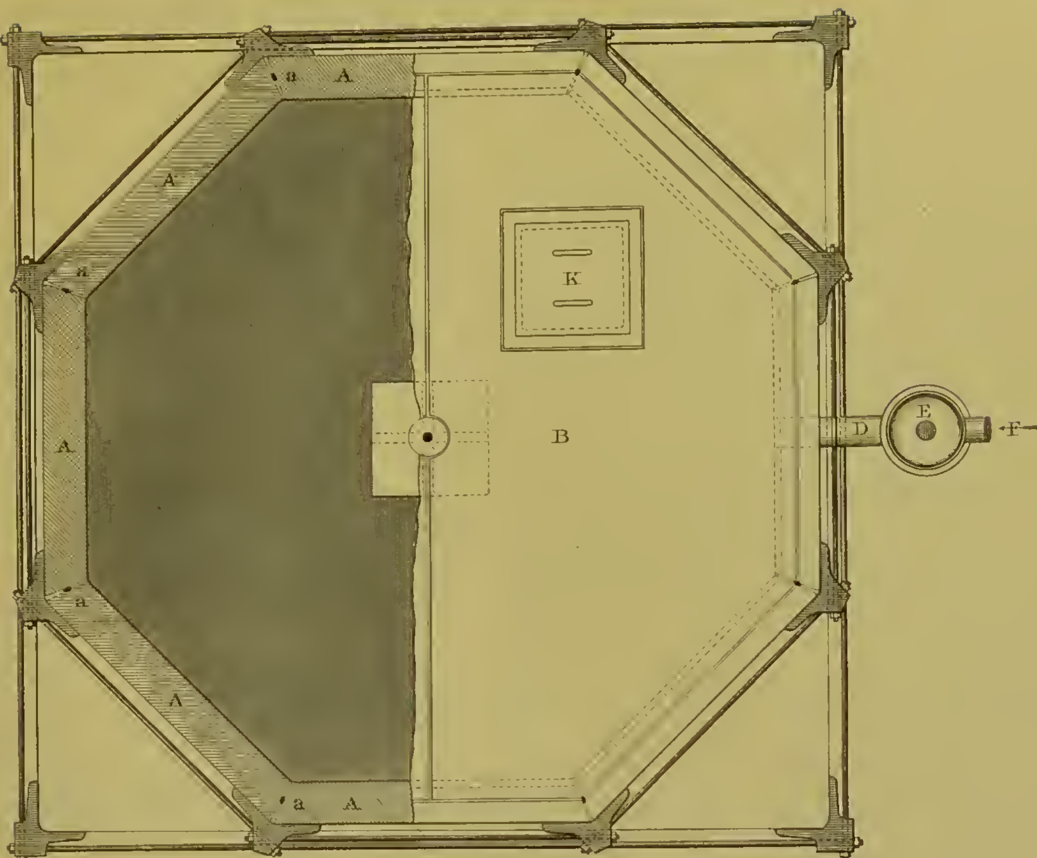


Fig. 1.

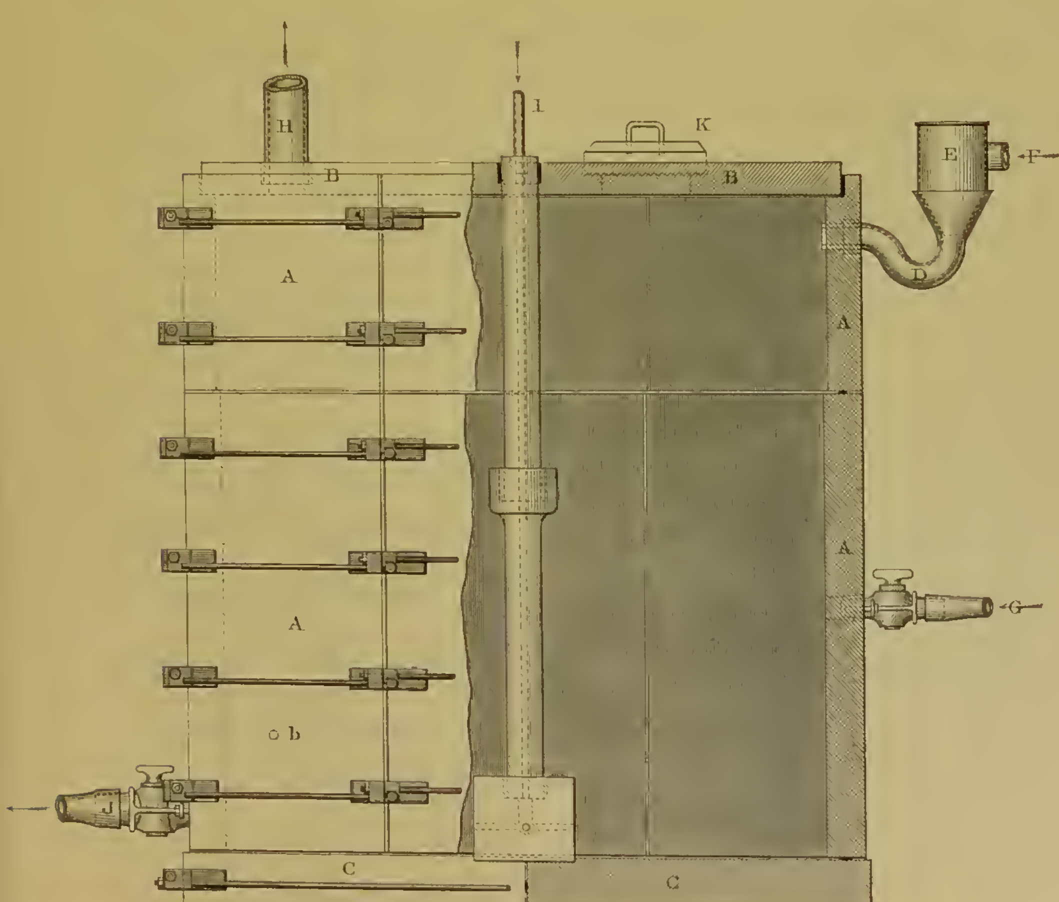


Fig. 2.

DEACON'S DECOMPOSING TOWERS

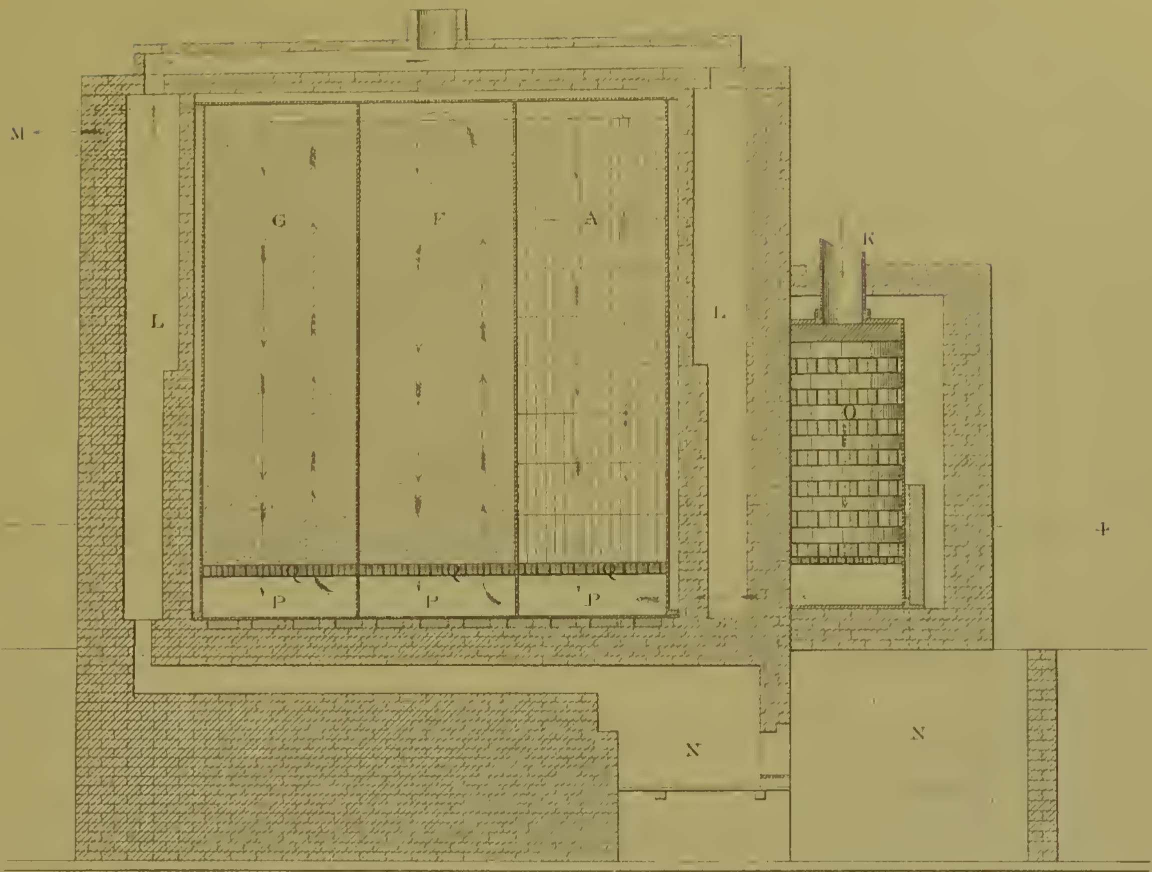


Fig 1.

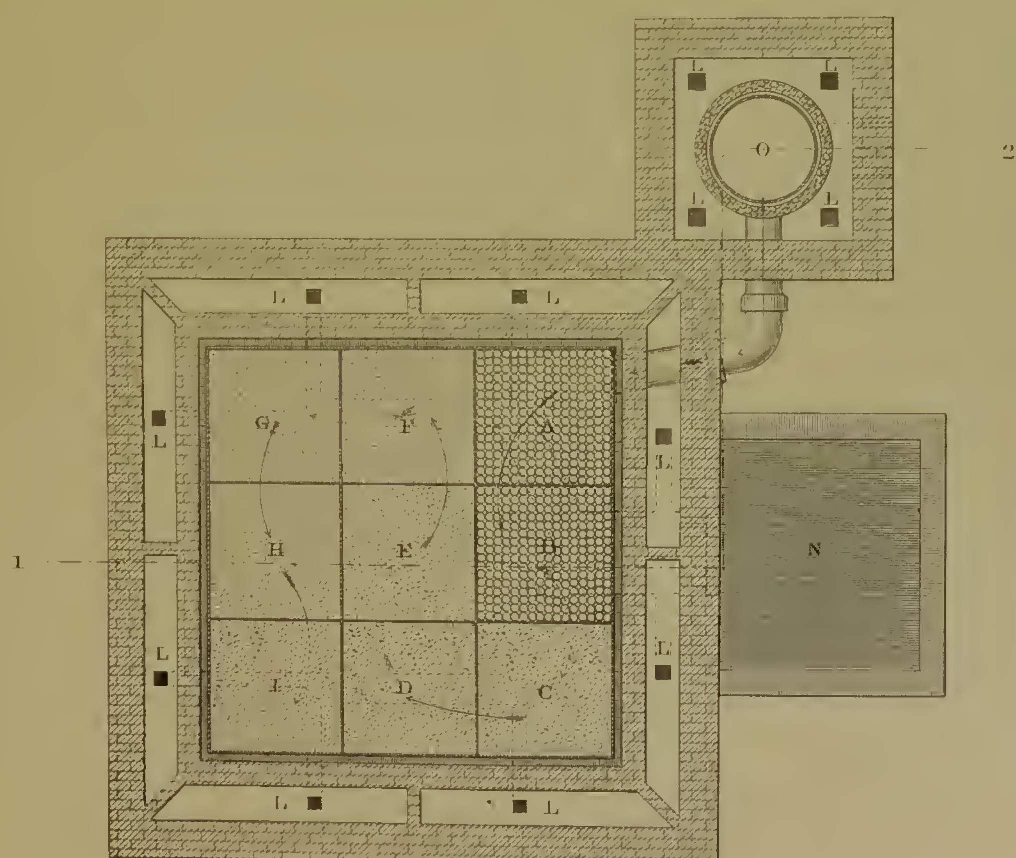


Fig. 2

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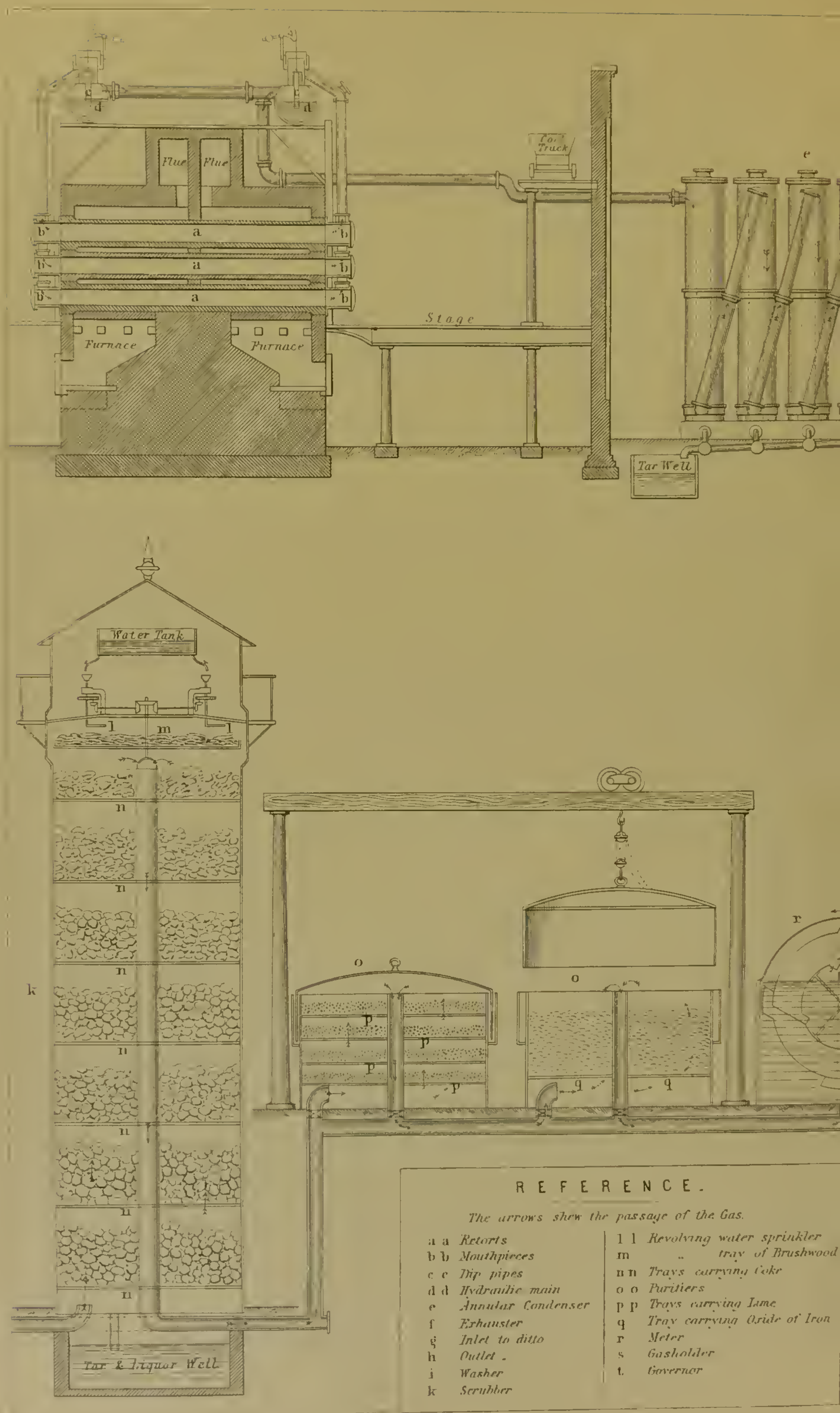
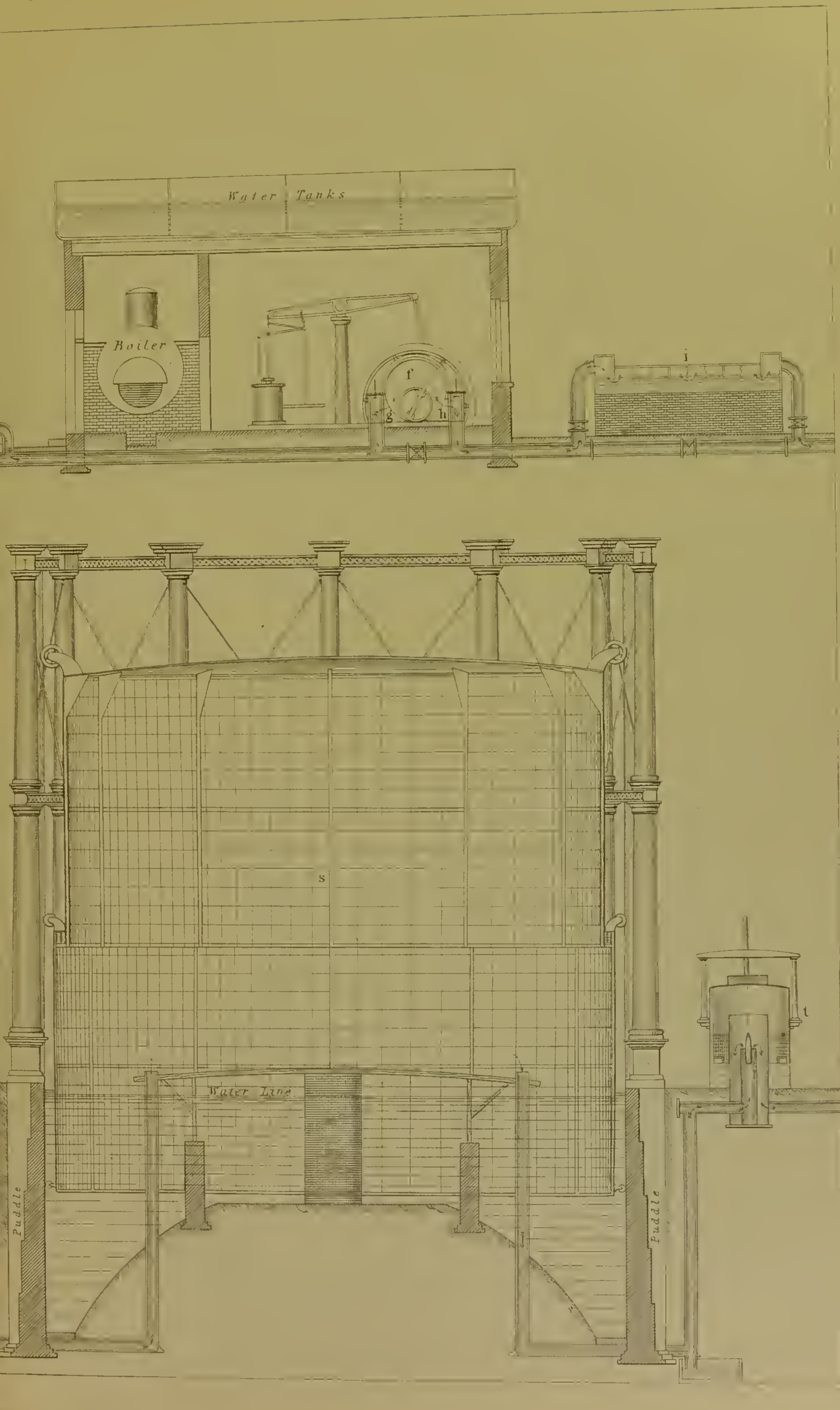
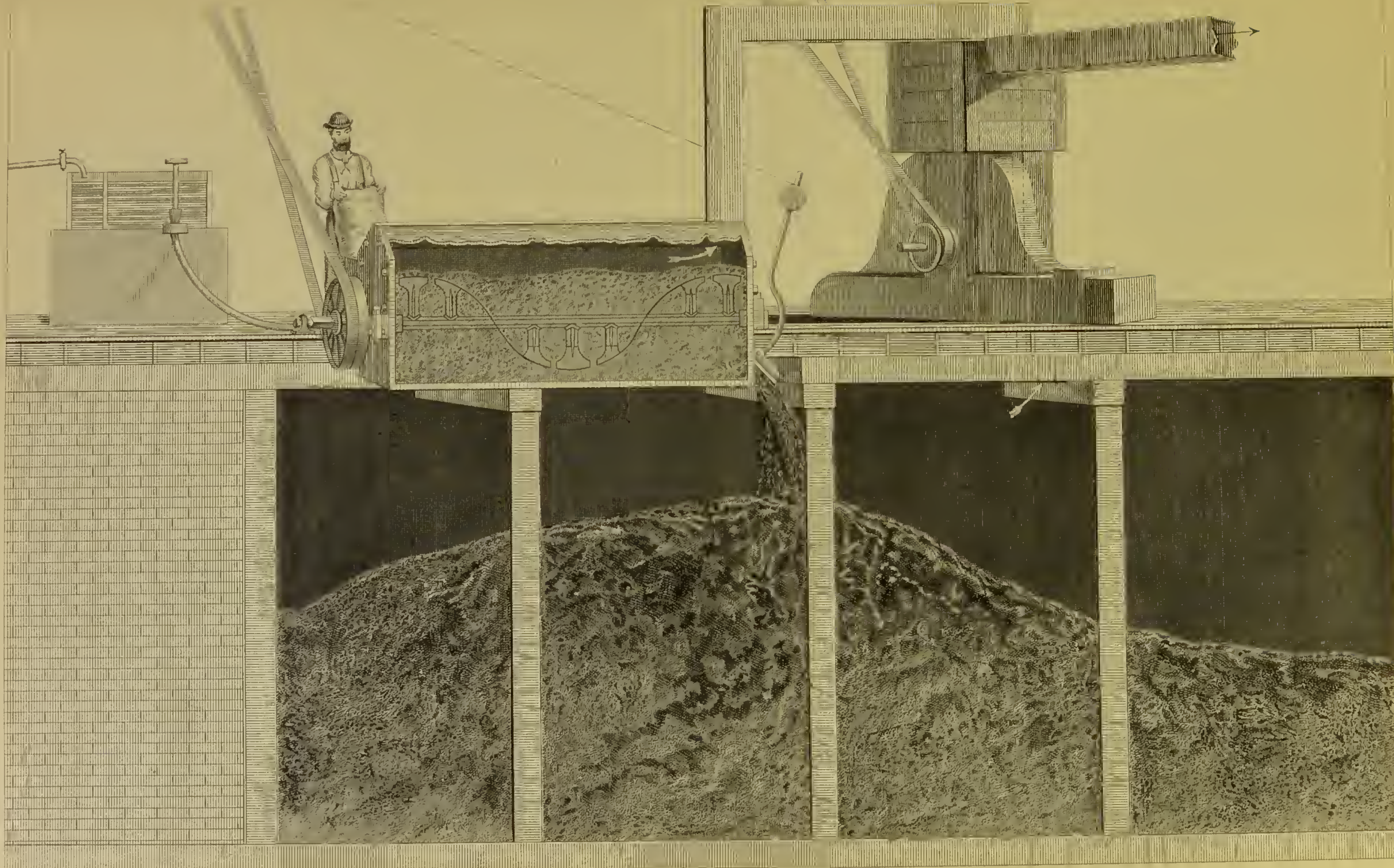


REFERENCE.

The arrows shew the passage of the Gas.

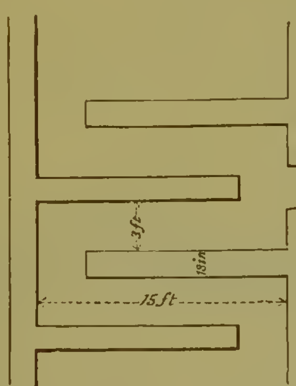
a a *Retorts*
b b *Mouthpieces*
c c *Dip pipes*
d d *Hydraulic main*
e *Annular Condenser*
f *Exhauster*
g *Inlet to ditto*
h *Outlet* .
i *Washer*
k *Scrubber*
l l *Revolving water sprinkler*
m " *tray of Brushwood*
n n *Trays carrying Coke*
o o *Purifiers*
p p *Trays carrying Lime*
q *Tray carrying Oxide of Iron*
r *Meter*
s *Gasholder*
t *Governor*


Water Tanks
Boiler
f
g
h
i
S
t
Water Line
Puddle
Puddle



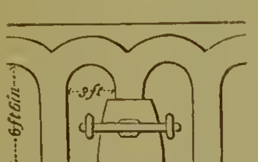
iron door luted on to the brick. The smoke from the calciner must be led through a great length of such chambers, for the double purpose of saving all that can be got of the arsenious acid, and of preventing the harm to the vegetation that would follow from the escape of any great quantity of it. The white arsenic that collects is cleared from the chambers about once a fortnight; it is found spread

Fig. 7.



or heaped on the floor, and attached to the walls, partly in a pulverulent, and partly in a crystalline form, but discoloured by coal soot. To clear out the chambers the furnaces must be stopped, unless (as is done in large establishments) there is arranged a double set of chambers, the two divisions of which diverge from the flue that collects the products of the furnaces, and converge again towards the stack. The object of this is to have one set of chambers free for emptying, while the other set is at work—dampers at the point of divergence regulating the direction of the current of the gases. Sometimes a separate range of chambers intervenes nearer the stack which shall take longer in filling, receiving but the last of the arsenical smoke, and needs to be cleared out but twice a year or so.

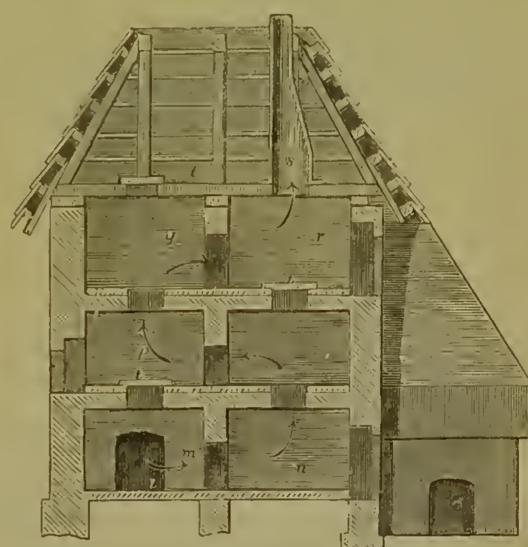
Fig. 8.



This product of the calcination is called arsenical soot; as before said, it is impure, being mixed with carbon, &c., from the furnaces, and probably containing some sulphur compounds. Some of it, indeed, may be white, but when all is mixed up together it is of a blackish grey colour. From many mines this is sold as it is to works where the plant is necessary for the next, the refining, process.

In Silesia, where the muffle furnace is used for the calcination, the condensing chambers are in a lofty building called the *poison-tower*, of which a section is shown in Fig. 9. The leading passages from the furnace, as shown in Fig. 5, communicate with the lowest room of the poison-tower. The vapours from the muffle (but not the gases from the fireplace) thus entering are made to traverse all the chambers it contains (following the direction of the arrows), and what is uncondensed (chiefly sulphurous acid) escapes at the top by the chimney, *s*. In the flues and first chambers of the tower the purest arsenic is to be found, that which is deposited in the upper ones being impregnated with sulphur. At the termination of the working of each charge, the covers, *t t*, are taken away for the purpose of collecting the whole of the condensed arsenious acid into the lower chamber, which is emptied only about once in every two months, and contains at that period about 25 tons of the impure compound. This product must be purer than the arsenical soot of the English process, not being mixed with particles of the fuel. It has not to undergo the process that we next describe, but goes at once for the making of arsenic glass.

Fig. 9.



2. *Refining or Resublimation.* — This is nothing more than a repetition of one form of the previous process. A long reverberatory furnace with sloping bed is used; this is not, however, quite so long as that intended for the ore, but it may be 18 feet in length, and 6 or 7 in width, with four side doors through which to work the charge. The arsenical soot is supplied at the upper end, and paddled down and spread pretty equable over the bed. As it volatilizes, more is added, and the action is kept up continuously for long; only when extraneous matters have so accumulated on the bed as to make it foul, is the firing stopped. It should be noted that, since in this last process it is very necessary to keep the volatilized product clean, and free from anything of a reducing power, it will not do to burn ordinary coal; a mixture of culm (anthracite) and coke is found to be best. The product of this second calcination (of which the chemical result is a complete

oxidation of all that was contained in the soot, and subsequent separation of the condensable oxide of arsenic) is collected in another set of chambers exactly like those above figured; and there may be the same looping of two lines of chambers which shall alternately be cleared out.

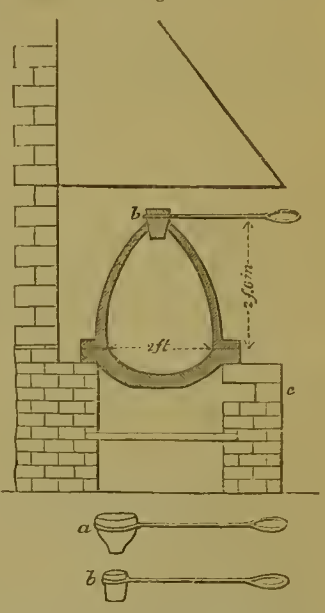
The arsenious acid as thus obtained is a beautifully white minutely-crystalline substance; it hangs on the walls and roofs of the chambers, and accumulates on the floor in glittering masses. After being collected it has to be prepared for the market by grinding in a mill just like a flour mill, from which, indeed, it comes out exactly like flour to look at. From the mill it goes to a hopper with a leather hose attached, which hose has at its end a collar and screw, by which it is fastened to the keg in which the white arsenic is to be packed; by a series of light blows on the cask the material is shaken down hard till the keg is thoroughly full, when it will hold 3 cwts. or 3½ cwts.; it is then ready for carriage.

In dealing in all these ways with such a poisonous substance as arsenious acid, certain precautions are necessary. The way in which it affects the men at the furnaces, &c., is in producing sores wherever it may collect and be allowed to stay. The men sometimes smear their faces with fuller's earth as a protection; without that the bad effects may be kept off by thorough cleanliness, by careful washing when the day's work is over.

With regard to the harm that may be done to the neighbourhood by the escape of arsenious acid from the stack, this has probably in many cases been confounded with that which arises from the sulphurous acid gas that spreads from the same stack; the chambers should be of length sufficient to intercept nearly all the arsenic.

Manufacture of White Arsenic Glass.—White arsenic glass is arsenious acid in an amorphous vitreous form. At the ordinary pressure of the atmosphere, arsenious acid volatilizes from the solid form, and solidifies at once from its vapour at the temperature of 185° C. (365° Fahr.); but it would seem that, under a slightly increased pressure, the vapour on condensing becomes for a moment a liquid, or we may say that, on solidifying from the gaseous state, it *passes through the liquid stage*, and hence the product is vitreous. The increased pressure causes the fusing and volatilizing temperatures to be distinct. Such, at all events, is our explanation of the result of the process now to be described. It consists of a re-sublimation of the white arsenic under new conditions. There are two somewhat different ways of effecting this. We will first describe the one followed at Swansea, in Wales. Fig. 10 represents the apparatus there employed. It consists of a cast-iron pan, 2 ft. across, surmounted by a bell of the same material, 2 ft. 6 in. high. The pan is fixed permanently over a fire, the bell is removable. The bell being adjusted as in the figure, and the pan being heated to a cherry-red heat, a charge of about ¼ cwt. of refined white arsensic is introduced through a hole in the top of the bell by the funnel marked *a*; the hole is then stopped by the plug *b*. The arsenious acid soon sublimes, and, on account of the heat of the vapour *under a certain amount of pressure*, it is deposited on the inside of the iron bell in an amorphous state—as a transparent glass, that which is an article of commerce under the name of white arsenic glass. As soon as the first charge has been worked off (and one can ascertain the state of it by introducing an iron rod through the plug-hole), another is introduced. The plug also may be from time to time removed to relieve the pressure if it should be too great; or if the fire becomes too hot, the brick *c* may be removed. For the first charge to be thus sublimed and condensed about two hours is required; the time necessary increases to three or four hours as the bell acquires a thicker cake. At the end of twenty-four hours the bell, with its contents, are removed, and a cold one takes its place; the arsenic glass formed inside the bell is about 1 inch thick; it is broken out and put in casks for transportation.

Fig. 10.



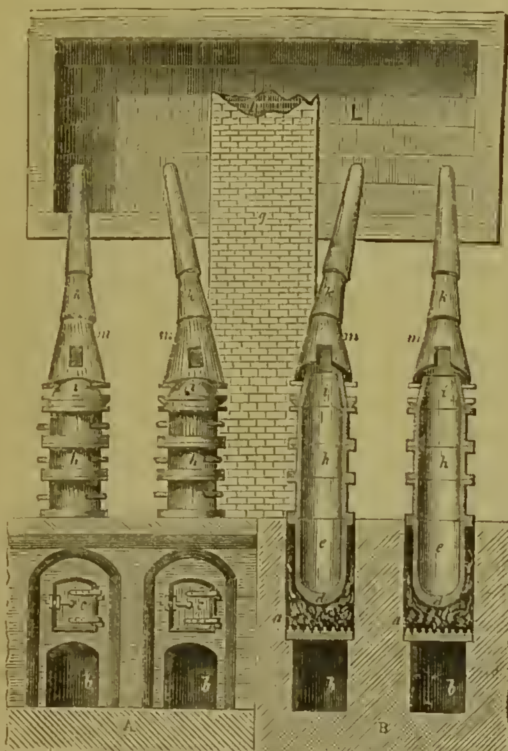
The method followed at Reichenstein, in Silesia, is somewhat different, though proceeding on the same principle. There the product of the roasting in the muffle furnace above described is submitted to treatment, which will be understood from the subjoined drawing, Fig. 11.

The part A is a front view, while B is a section of the apparatus employed. *a*, *a*, are the fire-grates, *b*, *b*, the ash-pits, *c*, *c*, the doors; the smoke from the various fire-places is carried off by the chimney, *g*; *e*, *e*, are subliming-pots of cast iron, into each of which a weight of about 3½ cwts. of the flour of arsenic is introduced; they are surmounted by the iron drums, *h*, *h*, and by the caps, *i*, *i*, which in their turn are covered by pipes, *k*, *k*, the narrow ends of which enter the condensing chamber, L. The pots being charged, the cylinders, *h*, *h*, are placed upon them by the aid of the handles with which they are furnished, and the joints being well luted with a composition of loam, hair, and blood, the caps, *i*, *i*, and the pipes, *k*, *k*, are adjusted, and, lastly, the fire is lighted. A very gentle heat is applied for about half an hour, after that time the heat is somewhat increased. If the heat be too feeble, the sublimate produced is similar to what was put in; if it be too

strong, much is driven into the pipes and the condenser. The result sought for is to obtain a vitreous homogenous mass in the cylinders. This should be produced at the end of twelve hours; the fire is allowed to go out, the cylinders are lifted off, and the arsenious acid glass is detached from them. Sometimes this acid is interspersed with dark spots of metallic arsenic; whenever this happens, either the whole compound must be sublimed anew, or those parts picked out if such an operation is practicable. By this process good crude arsenious acid yields from three-fourths to seven-eighths of its weight of the glass.

It is clear that in this process there is the same condition—of somewhat increased pressure—which, in the previously described one, was pointed out as the cause of the vitreous state of the product.

Fig. 11.

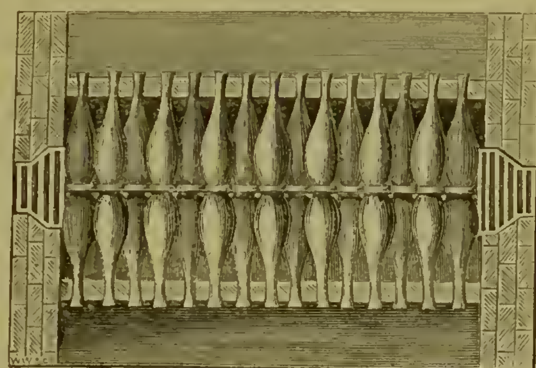


Arsenious acid is used for the following purposes:—For destroying the colour communicated by protoxide of iron, and for other purposes in glass-making; in dyeing and calico printing; in the preparation of various arsenical compounds which are used as pigments; in the manufacture of aniline dyes; and by naturalists (in the form of arsenical soap) to preserve organic specimens from putrefaction and from the ravages of insects. In medicine it is used only to a limited extent.

MANUFACTURE OF REALGAR.—Realgar (the composition of which is AsS_2) is made artificially by distilling a mixture of arsenical ores (ores containing arsenical and iron pyrites) with sulphur, or the sulphide of arsenic precipitated in purifying sulphuric acid. The materials should be mixed so as to contain 15 per cent. of arsenic and 26 to 28 per cent. of sulphur, since much of the sulphur will be driven off in the process. A furnace and gallery are erected, in which a number of earthen retorts are placed, as seen in the annexed cuts, Figs. 12 and 13.

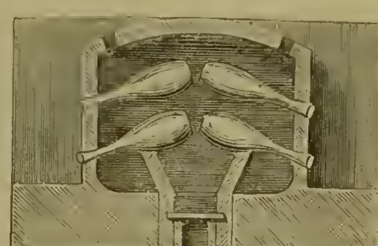
The retorts (which are of earthenware) are charged every twelve hours with 60 lbs. of ore to each; they are connected with similar vessels for receivers, which are permeated by a number of small holes to allow the gases to pass off. The charge fills the retorts to about two-thirds of their capacity. They are then gradually heated to redness, and kept in

Fig. 12.



that state for eight, ten, or twelve hours, when the furnace is allowed to cool; the receivers are taken off, and the crude realgar taken from them for remelting. The crude product is almost sure to have either too much arsenic or too much sulphur; it is preferred that it should be a compact dark substance, rich in arsenic, and still requiring sulphur, rather than that it should be a friable light red substance requiring arsenic. The remelting is done quickly in cast-iron pans; the mass is stirred up and the slag is removed; then sulphur or arsenic (as may be required according to its colour), or else other realgar having opposite qualities, is added, and again there is a stirring and a removal of slag. When the glass flows off thin from the iron rod, and when on cooling it shows the proper colour and compactness, then the liquid mass is let off into conical moulds of sheet iron, from which, when cold, the glass is turned out in lumps and broken up. The average composition of the product is—

Fig. 13.



Arsenic,	75 per cent.
Sulphur,	25 per cent.

MANUFACTURE OF FLY POISON (FLIEGENSTEIN).—At Reichenstein, at Rebas in Spain, and at Freiberg, the ores richest in arsenic are usually sublimed for fly powder. These rich ores, if used for realgar,

would stop the neck of the receiver with metallic arsenic. The process is carried on in a mode similar to that last described, but between the retort and the receiver, or rather partly in each, there is a piece of sheet iron, spirally rolled and coated with clay; in the interspaces of this the greater part of the arsenical vapour (fly poison) is condensed. The receivers have a little door of sheet iron, which remains closed till towards the end of the operation, when it will be necessary to observe the interior. The retorts themselves are glazed inside with a mixture of clay, blood, calves' hair, iron scale, and alum.

MANUFACTURE OF ORPIMENT.—The composition of orpiment is theoretically As_2S_3, but, as will be seen, the commercial product differs from this. It is a substance of a beautiful lemon or orange-yellow colour. It may be made by adding sulphur to realgar, but it is more commonly produced by fusing a mixture of arsenious acid and sulphur in the same kind of cast-iron pots as are used in making the white arsenic glass; it must be done at a temperature when the sublimate will just melt on the rings which surmount the pots. The proportion of sulphur used, as well as the proportion found in the product, vary much; perhaps the most beautiful colours are produced when from one-third to one-fifth of the mixture put into the pots is sulphur; but for the lighter kinds there is a much smaller proportion of sulphur. The result is probably a mechanical mixture of the sulphide with the oxide of arsenic.

The formula of orpiment is As_2S_3; it is the trisulphide of arsenic. Realgar is the disulphide (As_2S_2).

Orpiment is oxidized by nitric and nitro-hydrochloric acids, and dissolved by alkalies and alkaline carbonates; an arsenite together with sulphide of the alkaline metal being formed. Carbonic acid is expelled when a carbonate is used. Heated in close vessels, orpiment fuses and sublimes; in air, sulphurous acid is evolved, and arsenious oxide produced.

This arsenic compound is still used as a pigment, and is occasionally employed in dyeing to reduce indigo, which is dissolved by the potassium hydrate used at the same time. Orpiment was once used to dye silks, by dissolving it in ammonia, and passing the weft through the solution thus produced. On hanging the cloth up in the stove-room, the volatile ammonia was expelled, and the colour remained fixed upon the cloth. These compounds are highly poisonous, and should be used with the greatest care.

Furriers and tanners make an aqueous paste with 9 parts of orpiment and 1 of quicklime, which they term "rusma." This paste is applied in dressing skins to remove the hair, and as a toilet preparation to remove superfluous hairs; but its use for the latter purpose is attended with great danger. It is now to a great extent replaced in tanning by the calcium sulphide solution obtained by dissolving the spent lime of gasworks.

In pyrotechny, orpiment is used as an ingredient of white fire.

ARSENITES.—Arsenious acid unites with all the mineral bases in various proportions, and forms with them definite compounds, which, however, are for the most part unstable and of little utility in a manufacturing or artistic sense; moreover, though the result of chemical research, they have been but little examined. Those to which the most interest is attached are, potassium arsenite, and the compounds known as *Scheele's green* and *Schweinfurth green*.

Arsenites give a light green precipitate with copper salts, and a light yellow precipitate with silver nitrate. All arsenites yield a precipitate with sulphuretted hydrogen when they are dissolved in hydrochloric acid. The arsenites of the alkali and alkaline earth metals are decomposed by heat into metallic arsenic and a salt of arsenic acid, thus:—

$$\underset{\text{Arsenious oxide.}}{5(As_2O_3)} = \underset{\text{Arsenic oxide.}}{3(As_2O_5)} + \underset{\text{Arsenic.}}{4As.}$$

POTASSIUM ARSENITE, an acid salt ($K_2O,2As_2O_3$), is formed by dissolving arsenious acid in a solution of caustic or carbonated alkali, and evaporating the solution; or by decomposing barium arsenite by potassium sulphate; double decomposition takes place.

From this body neutral or monopotassic arsenite is obtained by boiling with potassium carbonate, and washing the residual compound with alcohol. Its formula is K_2O,As_2O_3.

ARSENITE OF COPPER ($(Cu_2O)_2As_2O_3$ or $Cu_3(AsO_3)_2$, *Scheele's Green.*—This compound derives its name from SCHEELE, its discoverer, who gives the following direction for preparing it:—Dissolve 2 pounds of sulphate of copper in 3 gallons of warm water; in another vessel make a solution of 2 pounds of pure potassa and 11 ounces of arsenious acid in 1 gallon of water; filter both through a cloth, and while warm, mix them portionwise, keeping the menstruum briskly agitated at each addition. As soon as the precipitate settles to the bottom, the clear liquid is to be decanted or siphoned off, and the green powder treated with a gallon or more of hot water, and agitated. Next it is to be thrown on a filter, again washed once or twice with water, and finally dried at a gentle heat.

Another process followed, is to dissolve 2 parts of sulphate of copper in 44 of hot water, and to add to this solution another composed of 2 parts of carbonate of potassa, 1 of arsenious acid, and 44 of water. The green powder which is thus produced is washed well with water, and dried at 212° Fahr.

It is likewise formed when a salt of copper is precipitated with potassium arsenite, or with arsenious acid, and a sufficient quantity of ammonia to neutralize the acid present.

SCHEELE'S green dissolves in an excess of ammonia, forming a colourless solution of arsenic acid and cuprous oxide.

There are also two hydrated salts: $CuH_4(AsO_3)_2$, and CuH,AsO_3.

ACETO-ARSENITE OF COPPER. *Schweinfurth Green, Imperial Green, Emerald Green* ($(CuAs_2O_4)_3Cu(C_2H_3O_2)_2$. —This pigment was first made in 1814, at the locality whence it takes its name. It is prepared by adding a solution of arsenious acid to verdigris.

In the cold, the change produced is different from that which subsequently results; a precipitate forms, which, instead of being of the rich colour of the compound, has an olive-green tint. On leaving the mixture for a long time to react, or by boiling it, a change occurs, and the olive-coloured precipitate becomes of a beautiful brilliant green hue. On the large scale it is manufactured thus: 10 parts of verdigris are diffused through sufficient water to form a thin paste, which is then passed through a sieve, after which 8 or 9 parts of finely-powdered arsenious acid are dissolved in 100 of boiling water, and the solution added while at the point of ebullition to the infusion of the verdigris in water in successive portions, care being taken to keep the mixture well stirred at each addition; and lastly, the whole is to be boiled for a few minutes, upon which the full tone of colour is developed. If cold water be poured into the hot solution without boiling, the peculiar green does not appear for some time; but a crystalline compound possessing a still richer hue is in this way produced, than by the foregoing method. In this country it is commonly sold as Emerald Green.

Another method is the following:—50 pounds of sulphate of copper and 10 of lime are dissolved in 20 gallons of ordinary vinegar, and a boiling hot solution of 50 pounds of arsenious oxide in water quickly stirred into it; the precipitate is dried and reduced to powder. In this process the precautions required to be taken in the preceding case are needful.

Both Scheele's Green and Schweinfurth Green are exceedingly poisonous, and should be used with great caution.

ARSENIC ACID.—*Arsenic oxide, pentoxide of arsenic; acide arsenique*, French; *arsensäure*, German; *acidum arsenicum*, Latin. Formula, As_2O_5.—This body was discovered by SCHEELE, who produced it by dissolving arsenious oxide (As_2O_3) in aqua regia—nitro-hydrochloric acid—and distilling the mixture to dryness in a retort. The residue is solid arsenic oxide. An easier method, however, of procuring this acid, is to dissolve arsenic in nitric acid, and to evaporate the solution to dryness: 4 parts of arsenious oxide are added very gradually to 3 parts of fuming nitric acid; the mixture becomes very hot, and in about twenty-four hours an oily liquid is produced, which consists mainly of arsenic acid; any unoxidized arsenious oxide is converted into arsenic oxide by the addition of a little more nitric acid.

Arsenic oxide is likewise produced by acting on arsenious oxide with any powerful oxidizing agent.

Arsenic oxide is deliquescent and crystallizable; it fuses at an incipient red heat, concreting on cooling into a vitreous mass. At a higher temperature it is decomposed, oxygen is evolved, and arsenious oxide sublimes. Its specific gravity is 3·7. To dissolve it, 6 parts of cold and 2 parts of boiling water are required. Its solution, which reddens vegetable blues, has an acid and metallic taste, and is a virulent poison, though less so than arsenious acid. The taste of the arsenic oxide is not very remarkable when dry, but when moistened it becomes exceedingly acrid. Arsenious acid gives a white precipitate with lime-water, a peculiar reddish-brown with nitrate of silver, and gradually yields a yellow deposit of trisulphide of arsenic when its solution is subjected to the action of a stream of sulphuretted hydrogen gas. Its precipitate with ammonia-sulphate of copper is pale greenish blue.

Arsenic acid forms three hydrates:—

Monohydrate,............ $As_2O_5H_2O = HAsO_3$.
Dihydrate,.. .... $As_2O_5(H_2O)_2 = H_4As_2O_7$.
Trihydrate,.............. $As_2O_5(H_2O)_3 = H_3AsO_4$.

Arsenic acid at high temperatures displaces all the more volatile acids from their salts. It is tribasic, but either one or two atoms of the metal may be replaced by hydrogen. Salts containing three and two atoms of metal are alkaline or neutral. Monometallic salts have an acid reaction. They may be represented thus:—

Monammonic or acid arsenate of ammonium,...$(NH_4)H_2AsO_4$.
Diammonic or neutral arsenate of ammonium,.$(NH_4)_2HAsO_4$.
Triammonic or basic arsenate of ammonium,....$(NH_4)_3AsO_4$.

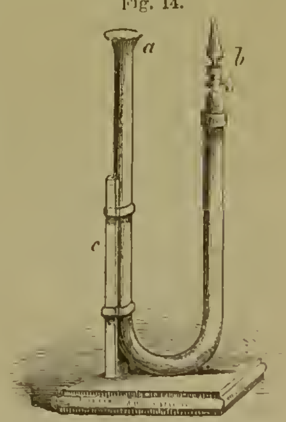
ARSENIC TRIHYDRIDE.—*Arsenious hydride, arsenetted hydrogen, arsine*, AsH_3.—Arsenic forms two compounds with hydrogen, the gaseous trihydride (AsH_3) and the dihydride (AsH_2), which is a brown powder. The trihydride only will be described.

Arsenic trihydride is a colourless gas, which can be liquefied by combined pressure and withdrawal of heat, but cannot be solidified. Its composition is analogous to that of ammonia. Its odour is particularly disgusting, and when breathed in even a very dilute state it produces nausea and giddiness. Animals immersed in it are at once killed. One volume of this gas contains 1·5 volumes of hydrogen and ·25 of arsenic vapour. Its vapour density is 2·695, air being unity.

DETECTION OF ARSENIC.—Arsenetted hydrogen is formed whenever hydrogen is evolved from a solution containing a salt of arsenious acid. Great care must be taken to avoid inhaling the gas, since fatal accidents have occurred through want of caution.

The combination of the two elements may always be effected by bringing together arsenious acid, or any arsenical compound, and zinc, water, and sulphuric or hydrochloric acid. This property was first taken advantage of as a test for the metal by MARSH of Woolwich. The apparatus he employed is shown in Fig. 14.

Fig. 14.



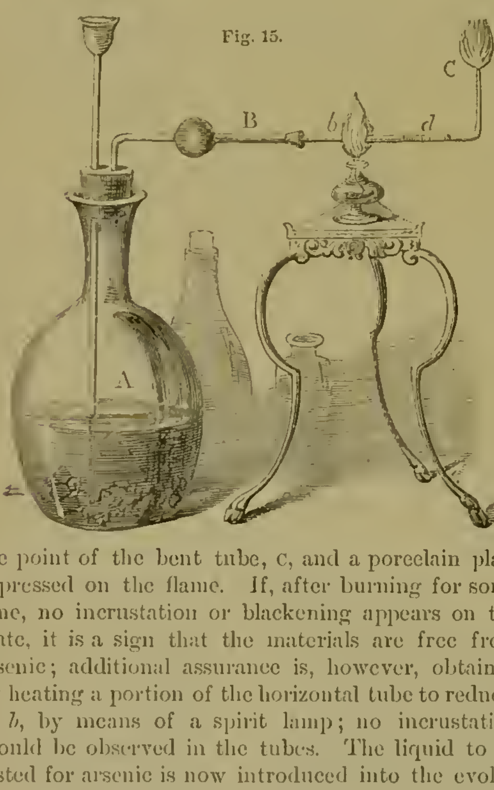
The stopcock, b, being removed, a few fragments of pure zinc are introduced into the bend of the tube, and pure dilute sulphuric acid then added; the jet, b, is fixed on, a is closed with the

thumb, and the gas evolved having been proved to be free from arsenic, by no deposit being formed when burned against a porcelain plate, the suspected liquid is then examined in a similar manner.

It deserves to be remarked, however, that pure zinc, especially when in large pieces, frequently dissolves so slowly in dilute sulphuric acid that it is impossible to obtain a steady hydrogen flame. The addition of a drop of bichloride of platinum, or of a small quantity of platinum black, will remedy this difficulty. If the fluid to be tested contains any considerable quantity of arsenic acid, this addition is sufficient to produce a violent reaction of the acid on the zinc.

All the apparatus based on the above principle are called after MARSH. Fig. 15 is a convenient form. The materials for generating the hydrogen are introduced into the evolution flask, A, and the gas, discharged through a tube, B, filled with dry cotton wool, is (sufficient time having been allowed to discharge the atmospheric air from the apparatus) inflamed at

Fig. 15.

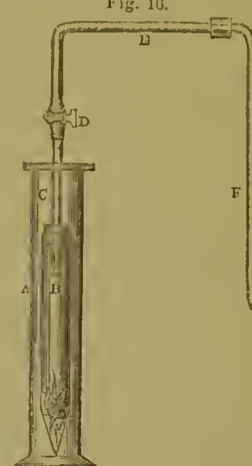


the point of the bent tube, C, and a porcelain plate depressed on the flame. If, after burning for some time, no incrustation or blackening appears on the plate, it is a sign that the materials are free from arsenic; additional assurance is, however, obtained by heating a portion of the horizontal tube to redness at *b*, by means of a spirit lamp; no incrustation should be observed in the tubes. The liquid to be tested for arsenic is now introduced into the evolution flask through the funnel tube; and if it contain any traces of the metal the flame of the hydrogen will acquire a bluish-white colour, from the reduction and separation of the arsenic, and fumes of arsenious acid will make their appearance. On bringing the porcelain plate in contact with the flame, brown arsenic spots, having a shining metallic appearance, will be obtained.

On directing the flame of the spirit lamp to the horizontal part of the tube, a beautiful incrustation of metallic arsenic, *d*, will be formed in the cold part; and on cutting off the end near the deposit, and applying heat, the arsenic is converted into arsenious acid, which may be dissolved in hot water, and tested by nitrate of silver or sulphate of copper.

The following, Fig. 16, is Dr. URE'S modification of MARSH'S apparatus:—A is a narrow glass cylinder, open at the top, about 10 inches high, and 1½ inch in diameter inside. B is a glass tube about 1 inch in diameter outside, drawn to a point at the bottom, and closed with a cork at the top. Through the centre of this cork the small tube, C, passes down air-tight, and is furnished at the top with a stopcock, into which the small bent hard glass tube (free from lead), E, is cemented. The bent tube, E, is joined to the end of F by a perforated cork.

Fig. 16.



This apparatus is to be used thus:—Introduce a few oblong slips of zinc, free from arsenic, into B, and then insert its cork with the attached tubes. Having opened the stopcock, pour into the tube, A, as much of the suspected liquid, acidulated with dilute sulphuric acid, as will rise to the top of the cork after B is full, and immediately shut the stopcock. The generated hydrogen will force down the liquid out of the lower orifice of B into A, and raise it above the level of the cork. The extremity of the tube, F, being dipped beneath the surface of a weak solution of nitrate of silver, and a spirit flame being placed a little to the left of the letter E, the stopcock is then to be slightly opened, so that the gas which now fills the tube, B, may escape so slowly as to pass off in separate small bubbles through the silver solution. By this means the whole of the arsenic contained in the trihydride of arsenic will be deposited either in the metallic state upon the inside of the tube, E, or with the silver will pass into the characteristic black powder. The first charge of gas in B being expended, the stopcock is to be shut till the liquid is again expelled from it by a fresh disengagement of hydrogen.

The ring of metallic arsenic deposited beyond E may be chased onwards, by placing a second flame under it, which forms it into an oblong, brilliant, steel-like mirror.

It is evident that, by the careful use of this apparatus, the whole of the arsenic in any poisonous liquid may be collected, weighed, and subjected to every kind of chemical verification. By means of the perforated cork, the tube, F, may readily be turned about, and its taper point raised into such a position as that, when the hydrogen issuing from it is kindled, the flame may be made to play upon a surface of glass or porcelain, in order to form the arsenical mirror.

Reinsch's Test.—A grey metallic film is produced when a perfectly clean strip of copper is immersed in

a hot solution of arsenious acid, or an arsenite mixed with hydrochloric acid. On washing the free acid from the coated copper, and then heating it in a solution of ammonia, the film peels off and separates, forming minute spangles of arsenide of copper, Cu_6As. It must, however, be borne in mind that this test is not by itself conclusive, since antimony and some other metals are likewise deposited upon copper under similar circumstances.

Bloxam's Test.—The occasional presence of arsenic in the sulphuric acid, and of both arsenic and antimony in the zinc, is, in C. L. BLOXAM'S opinion, a strong objection to the use of MARSH'S test; another objection being that the liquid which has been examined by this method for arsenic and antimony cannot be examined for other metals, on account of the presence of so large a quantity of sulphate of zinc, a consideration of much importance in cases where the quantity of the suspected matter is small.

The detection of poisonous metals by the decomposing action of the voltaic current is free from these drawbacks, and such minute quantities of poisonous metals may be detected by BLOXAM'S method of testing, that it may safely be relied on in most cases of chemico-legal investigation.

The apparatus most suitable for the detection of arsenic by electrolysis, consists of a two-ounce narrow-necked bottle, the bottom of which has been cut off, and replaced by a piece of vegetable parchment tightly stretched over it, and secured by a ligature of thin platinum wire (vulcanized caoutchouc is speedily corroded). The bottle is furnished with a cork carrying a small tube bent at right angles, and connected with a drawn-out reduction tube by a caoutchouc tube, and a funnel tube for pouring in the acid and solution to be tested; through this cork also passes a platinum wire bent into a hook inside the bottle, for suspending the negative plate. The bottle is placed in a glass of such a size as to leave a small interval between the two, the whole apparatus being then placed in a large vessel of cold water. An ounce of dilute sulphuric acid is next introduced into the bottle and its outer glass shell, so as to fill both to the same level; the positive plate being immersed in the acid contained in the outer space.

The current of a voltaic battery (six Grove's cells) is then passed through the arrangement, and when the bottle is filled with hydrogen, the shoulder of the reduction tube is heated to redness for fifteen minutes to ascertain the purity of the sulphuric acid, after which the liquid to be tested is introduced into the bottle by means of a pipette; a drachm of alcohol is afterwards added to prevent potting; the cork is removed for as short a time as possible: $\frac{1}{1000}$ of a grain of arsenic diffused through a large bulk of liquid can be detected by this apparatus.

QUANTITATIVE ESTIMATION.—Arsenic is quantitatively determined in various ways.

As Sulphide.—In general cases, when the liquor contains substances not precipitated by sulphuretted hydrogen, the arsenical solution may be acidified with hydrochloric acid and determined by passing through it a current of sulphide of hydrogen. If the liquor be dilute, a precipitate of trisulphide of arsenic is produced, the composition of which corresponds to that of arsenious oxide. The stream of sulphuretted hydrogen is continued until the liquor is completely saturated, the whole is then left at rest in a moderately warm place until the odour of the gas has vanished, when the traces of trisulphide of arsenic held in solution by the excess of the gas are thrown down. A small portion of the precipitate commonly adheres so strongly to the side of the vessel, and of the glass tube which dips in the liquor, that it cannot be removed by mechanical means; this is very easily dissolved by a few drops of ammonia, and the solution added to the acid liquor, which reprecipitates the small quantity of dissolved trisulphide of arsenic. If the liquor contains any oxide of cobalt which is to be subsequently determined, a solution of carbonate of soda must be employed instead of ammonia, because oxide of cobalt cannot be completely precipitated by potassium hydrate from a solution which contains ammonia.

The trisulphide of arsenic, which is of course mixed with some free sulphur, is collected upon a tared filter, washed, dried at a very gentle heat, and then weighed. All that can be shaken from the filter is then put into a glass vessel, and the filter is again weighed in order to know the amount of substance submitted to experiment. Aqua regia or hydrochloric acid and potassium chlorate is then added to it, and the whole left to digest for some time. The action of the acid upon trisulphide of arsenic in fine powder is very energetic, even in the cold, owing to which the oxidation must be performed in capacious vessels. The arsenic is oxidized into arsenic oxide, and a portion of the free sulphur is converted into sulphuric acid. In order to convert the whole of the sulphur into sulphuric acid, the digestion in aqua regia, which would need to be frequently renewed, would require too long a time. On this account, as soon as the sulphur is agglomerated into small lumps, it is collected upon a counterpoised dry filter, washed, dried most carefully, and weighed. A solution of chloride of barium is added to the filtered liquor, and the sulphate of barium determined with the usual precautions; from its weight, that of the sulphur in solution is calculated. The sulphate of barium is very difficult to wash, on account of the presence of nitric acid in the solution. The collective quantities of sulphur indicate the amount which existed in the sulphide of arsenic subjected to analysis; the loss indicates the loss of the arsenic, from which the proportion of the arsenious acid is calculated. It is necessary to take care, in this operation, to collect the undissolved sulphur only after a prolonged digestion in aqua regia.

Or, the dried mixture of trisulphide and sulphur may be decomposed by ignition in an atmosphere of hydrogen, when the sulphur will be removed as sulphuretted hydrogen, and a residue of metallic arsenic will remain behind.

Instead of the preceding method the following may be adopted:—The acid liquor is supersaturated with ammonia, and a quantity of ammonium sulphide is

added which produces a precipitate of tri- and penta-sulphide of arsenic, which dissolves easily and completely in the excess of sulphide of ammonium.

If the solution is very concentrated, it should be diluted with a large quantity of water, and hydrochloric acid carefully added, till it gives a feeble acid reaction with litmus paper. Trisulphide of arsenic is thereby precipitated, with disengagement of sulphuretted hydrogen. The liquor is digested at a gentle heat, until the odour of the sulphide of hydrogen has disappeared, and the arsenic trisulphide produced is separated by filtering.

It is absolutely necessary to proceed with this sulphide as in the former case, because it is mixed with much sulphur from the decomposition of the sulphide of ammonium. If the operator has not added a very large quantity of water to the solution of the sulphides of arsenic in sulphide of ammonium, before decomposing by hydrochloric acid, and too large a proportion of acid is subsequently added, the whole of the arsenic is not obtained in the state of sulphide. It is better, in most cases, to decompose the liquor with acetic, instead of with hydrochloric acid.

As Arsenate of Lead. (Pb_3AsO_4).—Arsenic acid is precipitated by a solution of acetate or nitrate of lead, in the state of arsenate of lead, from the weight of which the quantity of the arsenic is determined; but this method is seldom satisfactory, and is attended with more difficulties than that just described, when the solution contains other metallic oxides.

It is also necessary to determine the quantity of the arsenic acid in the arsenate of lead produced, in order to obtain anything like tolerable accuracy; this procedure is much more complicated than the quantitative determination of arsenic in the state of sulphide.

Or, according to FRESENIUS, if arsenious acid is present, convert into arsenic acid by adding nitric acid and evaporate to a small bulk. Add a weighed quantity of recently ignited pure oxide of lead (about 6 times the quantity of arsenic acid present), evaporate to dryness, and heat to gentle redness for some time. When much nitrate of lead is present this ignition requires considerable care to prevent loss by crepitation. The residue consists of arsenate of lead and oxide of lead; in other words, of arsenic acid and oxide of lead. Subtract the weight of the oxide of lead from that of the residue, and the remainder is the weight of the arsenic acid.

As Arsenate of Magnesium and Ammonium.—In the presence of arsenious acid, add hydrochloric acid, heat gently, add chlorate of potassium in small portions, and then allow to stand at a gentle heat till the chlorous smell has nearly gone off.

Add ammonia in excess (the solution should remain clear), and then magnesium sulphate, previously mixed with ammonium chloride, in sufficient quantity to prevent its being precipitated by ammonia. Allow to stand for twelve hours in the cold. Decant through a weighed filter, transfer the precipitate to the filter with the aid of portions of the filtrate, and then wash with small quantities of weak ammonia (the ordinary solution diluted with 3 parts of water), till the washings are nearly free from chloride. Finally dry the precipitate at 240° Fahr. (100° C.). Its formula is $2(Mg_2(NH_4O)AsO_4) + H_2O$.

The results are always too low, as the precipitate is perceptibly soluble even in ammoniacal water.

Or, precipitate by sulphuretted hydrogen (in the presence of arsenic acid at a temperature of 158° Fahr., 70° C.). Filter, wash, and dry the precipitate. Transfer it as completely as possible to a porcelain dish, add a good quantity of the strongest nitric acid, cover the dish, and after a little while place it on a water bath, then heat till all the sulphur has disappeared and the nitric acid is almost completely evaporated. Extract the filter with ammonia, evaporate the solution to dryness, oxidize the residue with nitric acid, and mix it with the bulk of the arsenic acid. Finally add excess of ammonia, precipitate with a mixture of magnesium sulphate and ammonium chloride, and proceed as above.

Volumetrically. By standard Bichromate of Potassium.—The arsenious acid in the solution to be examined is oxidized by a standard solution of bichromate of potassium, and the excess of the latter is estimated by a standard solution of ferrous sulphate. The solutions are prepared thus:—

Solution of arsenious acid.—Dissolve exactly 5 grm. arsenious acid in potash, add hydrochloric acid in slight excess, then 100 c.c. more hydrochloric acid of 1·12 spec. grav., and dilute to 1 litre.

Solution of bichromate of potassium.—Dissolve about 2·5 grm. to 1 litre.

Solution of ferrous sulphate.—Dissolve about 1·1 grm. iron wire in 20 c.c. dilute sulphuric acid, and dilute to 1 litre.

To find the relation between the chromate solution and the iron solution.—Run into a beaker 10 c.c. of the chromate solution from a burette, add 5 c.c. of hydrochloric acid and 50 c.c. of water, and then titrate with the iron solution till a drop taken out ceases to give a blue colour with a drop of ferricyanide of potassium on a white plate.

To standardize the bichromate solution.—Transfer 10 c.c. of the arsenic solution to a beaker, add 20 c.c. of hydrochloric acid of 1·12 spec. gr., and 80 to 100 c.c. water;* run in chromate solution till the yellow colour of the fluid shows an excess, wait a few minutes, add excess of iron solution, then again 5 chromate solution, finally, again iron solution till the end-reaction appears. Deduct from the total quantity of chromate solution employed the amount corresponding to the iron used.

For the actual analysis.—Dissolve the substance in hydrochloric acid. The solution should contain not less than $\frac{1}{6}$th of its volume of hydrochloric acid of 1·12 spec. gr. It is not advisable, on the other hand, that it should contain more than $\frac{1}{2}$, otherwise the end-reaction with ferricyanide of potassium is slower in making its appearance, and loses its nicety. Now proceed as directed above for the standardizing

* The water must be measured, for the oxidation is normal only when the fluid contains at least $\frac{1}{6}$th of its volume of hydrochloric acid of 1·12 spec. gr.

of the bichromate solution. If the direct determination of the hydrochloric acid is not practicable, precipitate the arsenic with sulphuretted hydrogen; wash the precipitate, transfer it with the filter to a flask, treat it with a nearly saturated solution of mercuric chloride in hydrochloric acid of spec. gr. 1·12, digest on a water bath till the precipitate is white, and dilute with a definite proportion of water. Then proceed as in standardizing the bichromate solution.

Separation from other metals.—Arsenic is separated from lead, mercury, silver, bismuth, cadmium, and copper, by digesting the mixed sulphides in an excess of ammonium sulphide, which dissolves the arsenic sulphides. The solution is subsequently filtered off, and the trisulphide of arsenic thrown down from the filtrate by addition or a slight excess of hydrochloric acid; and on the deposited sulphide being refiltered, washed, dried, and treated as before stated, the amount of arsenic is found. Antimony and tin are most difficult of separation from this metal.

When the arsenic and antimony are in the form of an alloy, they may be completely separated by heating it to redness in an atmosphere of hydrogen or carbonic acid gas, in an apparatus similar to Fig. 11, p. 251; the arsenic thus volatilizes and the antimony remains behind. When the quantity of arsenic is considerable, it is essential that the diameter of the tube, fused on to the further side of the glass bulb containing the alloy, be not too small.

As soon as the apparatus is filled with hydrogen gas, heat is applied to the bulb, and is continued until no more metallic arsenic is deposited in the end tube. By means of a small spirit-lamp, the metal is constantly expelled from the tube, leaving it clear.

When the arsenic has been completely eliminated from the tube, the glass bulb is suffered to cool, but without interrupting the current of gas. It is then weighed with the residuum of metallic antimony, and the loss indicates the quantity of arsenic. It is necessary in this operation not to employ too strong a heat, which would slightly volatilize the antimony. It is scarcely necessary to add, that the operator should take great care not to inhale the arsenical vapours, on which account the experiment must not be conducted in the laboratory, but under the hood of the furnace opening into the chimney-flue.

Nearly all the arsenic found in nature, under the name of *native arsenic*, contains small quantities of antimony, which may be determined by the previous method.

When, however, antimony and arsenic exist in solution, or when the two metals being combined in the solid state are united with other substances, so that the method which has just been described cannot be employed, another process must be adopted to separate them from each other. The solution is diluted with a sufficient quantity of water after having added tartaric acid thereto, without which precaution the addition of water would render it milky.

If the combination under examination consists of a regulus of the metals, it is dissolved in aqua regia, tartaric acid is poured into the solution, and water is then added. A current of sulphuretted hydrogen is next passed through the liquid till it is saturated; it is then very gently heated, in order that the metallic sulphide may settle completely. When the solution contains arsenic acid the first precipitate formed is trisulphide of antimony, and it is only after some time that the trisulphide of arsenic falls down, so that at first a layer of an orange-red colour is deposited, which is covered afterwards by another layer of a pale canary-yellow colour. Before filtering it is necessary to mix these two layers well together by stirring with a glass rod. The whole is then filtered through a weighed filter, upon which the sulphides are dried at an extremely gentle heat until their weight remains constant. After having determined the weight of these sulphides, a portion —about half of it—is shaken down into a glass, the remainder is very gently heated again with the filter, and the whole is weighed for the purpose of ascertaining the weight of the portion about to be operated upon. The portion in the glass is to be treated very cautiously with aqua regia till the sulphides are oxidized.

Tartaric acid is then added to the solution, which is to be diluted with water. If any sulphur has separated, it must be filtered from the liquor, and its quantity ascertained. Chloride of barium is now poured into the filtrate, to precipitate the sulphuric acid which has been formed. From the weight of sulphate of barium, that of the sulphur which it contains is calculated, and the portion of sulphur which has not been oxidized by the nitro-hydrochloric acid is added to the quantity previously determined. The whole of the sulphur contained in a given weight of metallic sulphide having thus been determined, it is easy to deduce the collective weight of the antimony and arsenic.

The quantity of antimony is determined in another portion of the mixed sulphides, in the same manner as directed for that metal. (See ANTIMONY.) When the amount of antimony and sulphur is known, the arsenic is easily found by deducting the united weights of those two bodies from the quantity of the mixed sulphides taken; the difference is the weight of the arsenic.

LEVOL estimates the arsenic which may be alloyed with copper and tin in bronzes as follows:—Having dissolved the compound in hydrochloric acid and evaporated to dryness, nitric acid is added, and the whole heated, which renders the tin insoluble in the form of binoxide or stannic acid, and the arsenious acid partially remains with it. The precipitate is dried and reduced by hydrogen gas. The reduction takes place at a dull red heat, the greater part of the arsenic being separated by sublimation; a small quantity still remains with the tin, but this is removed by treating the alloy with hydrochloric acid, which dissolves the tin, leaving the other constituent undissolved. The compound may also be acted upon by zinc and sulphuric or hydrochloric acid, by which treatment the whole of the arsenic is removed in the

form of gaseous trihydride, from which the metal may be abstracted, and its quantity estimated by transmitting the gas through a solution of protoxide of tin of known strength, at a slightly elevated temperature: the arsenic is taken up by the tin, and may be found by the increase of the weight of the latter.

BALSAMS.—*Baumes*, French; *balsame*, German.—This term was formerly applied to all liquid vegetable resins, as well as to a great number of pharmaceutical preparations. French chemists formerly confined the term balsam to vegetable substances composed of benzoic acid with more or less volatile oil. But as this excluded copaiba and some other substances, popularly called balsams, most chemists retain the old acceptation, and consider as balsams the viscid aromatic resinous fluids which exude from many growing plants, whether they contain benzoic acid or not. Balsams are divided into two classes—those which do not, and those which do, contain cinnamic acid.

Oleo-resins.—To the first class belong the different turpentines of coniferous plants; Canada balsam; copaiba; and opobalsamum, or Mecca balsam. They are semi-liquid, resinous, or glutinous juices, which flow spontaneously or by incisions from various vegetables, especially those belonging to the orders Coniferæ, Terebinthaceæ, and Leguminosæ. They have a hot and acrid taste and a strong odour, which in some is very fragrant, in others less agreeable, but still peculiar.

Balsams consist of a volatile oil and resin. The resins are produced by the oxidation of the oils, so that a balsam is an intermediate product between the two. The odour of balsams, their semi-liquidity, and most of their medicinal activity, is owing to the oil which they contain. This oil may be procured from them by distillation: it volatilizes when they are exposed to air, causing them to become hard.

Benzoin and dragon's blood are styled balsams, but more properly belong to the resins, which see. True balsams are more or less viscid liquids, which yield volatile oils on distillation with water.

The class of bodies comprehended under the general name of balsams has not been forgotten in that active investigation of organic bodies to which several chemists have, with peculiar predilection, devoted themselves, especially since the discovery of easier and more certain methods of research than those formerly known have removed the chief difficulties. In former times, the analyses of the balsams were purely qualitative; everything crystalline, and which united with a base, was considered as benzoic acid; those which did not enter into union were described as camphor. If, on distillation, a volatile fluid passed over, it was deemed sufficient to state that the substance contained also a volatile oil. At the present time greater precision is required, and every constituent of a compound is submitted to careful investigation.

CANADA BALSAM; *Baume de Canada.*—This is a turpentine from the Balm of Gilead fir, *abies balsamea*, a conifer which is indigenous to Canada, Virginia, and Carolina. It is slightly yellow, transparent, possesses an agreeable terebinthic odour, and an acrid taste. When fresh it flows readily and is turbid, but in time solidifies and in doing so becomes bright and clear. BONASTRE analyzed this balsam, and found the following:—

	Centesimally represented.
Essential oil,	18·600
Resin, soluble in alcohol,	40·000
Resin, difficultly soluble,	33·400
Elastic resin,	4·000
Bitter extractive and salts,	4·000
	100·000

The sparingly soluble resin is friable, heavier than water, and becomes electrical by friction. A similar balsam is obtained from *abies Canadensis.*

Its index of refraction is 1·532. It turns a polarised ray of light to the right. When exposed to the air in thin layers, it becomes perfectly hard in about forty-eight hours. It is used for cementing together the various parts of many optical instruments, and is of peculiar value in the Nicol prism. Total reflection only takes place when a ray of light escapes from a more refracting to a less refracting medium, but it always, under these circumstances, takes place when the obliquity is sufficient. Now the refractive index of Iceland spar is for the extraordinary ray less, and for the ordinary ray greater, than for Canada balsam. An able optician named NICOL, taking advantage of this, cut a crystal of Iceland spar in two halves in a certain direction. He polished the severed surfaces and reunited them by Canada balsam, the surface of the union being so inclined to the beam traversing the spar that the ordinary ray, which is the most highly refracted, passes from a more refracting to a less refracting medium on passing from the spar to the balsam and is therefore totally reflected; whilst the extraordinary ray passes from a less refracting to a more refracting medium, where total reflection cannot occur, and consequently issues at the other extremity of the instrument.

COPAIBA or CAPAIVA BALSAM (*Baume de Copahu*, French) is obtained from incisions made in the trunk of several species of *Copaifera*, which grow in the Brazils, Peru, Mexico, and the Antilles. The incisions are made in the trees in the rainy season; a single incision often yields 12 lbs. of the balsam.

It is of a light yellow colour, rather liquid, transparent; has a bitter, sharp, burning taste, a suffocating and unpleasant smell; specific gravity, 0·920 to 0·985; soluble in absolute alcohol, partially dissolved by spirit of wine, and gives, with alkalies, crystalline compounds. It dissolves with the aid of a gentle heat one-fourth its weight of carbonate of magnesia, and remains translucent. The analysis yields the annexed:—

	Centesimally represented.
Volatile oil,	38·00
Soluble resins, copaivic acid,	52·75
Brown soft resin,	1·66
Water and loss,	7·59
	100·00

The oil contains no oxygen, has a composition like

oil of turpentine, and according to DURAND dissolves caoutchouc.

Copaiba balsam is used for making paper transparent, for certain lacquers, and in medicine. In the latter, PEREIRA states the oil to be preferable to any preparation of the balsam.

Paracopaiba Balsam.—This contains from 20 to 25 per cent. more essential oil than copaiba, which renders it more liquid, but the oils from both kinds of balsam are identical in odour and in all other properties; and the residuous resin in both kinds becomes equally hard and brittle, which entirely does away with the supposition of its having been sophisticated with any fat oil: the two resins, however, differ; the copaiba containing chiefly acid resins, and paracopaiba neutral resins.

Paracopaiba balsam is thinner, and of a lighter yellow colour than the ordinary kind, so that it is strikingly distinguished from the latter by this character. It possesses the disagreeable smell of the balsam of copaiba, and the peculiar persistent taste, in perfect purity. The specific gravity is 0·94. Mixed with solutions of potassa or ammonia, it remains in all proportions turbid, and after some time it again separates from these liquids. In alcohol it does not perfectly dissolve, like the ordinary copaiba balsam, but forms with it a milky liquid. This is on account of its containing a resin, which does not dissolve in alcohol. It contains 82 per cent. of oil and 18 per cent. of resin.

In order to obtain the volatile oil common to the two forms of balsam in a pure state, the balsam is twice distilled with water, and the oil thus procured, which is quite clear, is then dried by chloride of calcium. It is thick, colourless, has a strong and pure copaiba smell, and an acrid, burning taste. Its specific gravity is 0·91; the boiling point is at 485° Fahr. The boiling oil readily becomes decomposed by the heat: it assumes a yellowish colour, becomes viscid, then brown, thick, and glutinous, and at last is perfectly decomposed, whilst carbon is separated. With ether it mixes in all proportions, but not with absolute alcohol, of which a rather large quantity is required for its complete solution. In common alcohol it dissolves with great difficulty; if dry ammoniacal gas be passed into it, it rapidly absorbs it and enters into combination, forming a reddish-brown fluid, which, if saturated, fumes in the air.

This oil is a hydrocarbon, and has the formula C_5H_8. Nitric acid, of 1·32 specific gravity, produces no reaction at common temperatures. If, however, it be heated, a violent reaction takes place, and the oil is converted into a resinous substance. If diluted nitric acid be employed, the mixture boils quietly without coming over, and within a few days the oil dissolves perfectly in the liquid. At the same time nitrous acid, carbonic acid, and peculiar volatile acids, are eliminated, which form, with acetate of lead, a precipitate, but which have not been further examined. The residue being evaporated and diluted with water yields an acid resin not affected by nitric acid, and a crystallizable acid, which remains in solution, whilst the former is precipitated. This resin is of a yellowish-red colour, dissolves in some degree in boiling water, and forms again a milky precipitate when cold. In ether and alcohol it dissolves with facility, and from the spirituous solution small resinous crystals are afterwards precipitated. It has a strong acid reaction, and forms, with potassa or ammonia, red neutral compounds, which are soluble in water.

The acid which is obtained after the evaporated nitric acid solution of the oil has been freed from the resin just described, by the admixture of water, crystallizes in thin, transparent, colourless laminæ. It dissolves easily in water, spirit of wine, ether, and petroleum, is inodorous and bitter, and has a slight acid reaction.

Fuming nitric acid detonates with copaiba oil without the application of heat. Iodine is dissolved by it, without effecting any brisk reaction. Chlorine produces a violent disturbance, hydrochloric acid vapour escapes, and the mass becomes yellow and viscid. Strong sulphuric acid produces a deep violet colour.

OPOBALSAM.—BALM OF GILEAD.—MECCA BALSAM.—This is a whitish, turbid liquid, flowing from incisions made in the *Balsamodendron Gileadense*, or *Amyris Gileadensis*, or Beshan of Arabia. It is very odorous, and on exposure resinifies. Its analysis gives—

	Centesimally.
Volatile oil,	30·00
Soft resin, insoluble in alcohol,	4·00
Hard resin, soluble in alcohol,	64·00
Extractive,	0·40
Loss,	1·60
	100·00

Its physiological effects are believed to be similar to those of balsam of copaiba and the liquid turpentines. It is never employed by Europeans, but the Asiatics use it for its odoriferous as well as its medicinal qualities, and ascribe to it most wonderful properties.

STORAX BALSAM.—This balsam is the product of *Styrax officinalis*, a handsome shrub growing in the Levant, Palestine, Syria, and Greece, and cultivated in the southern parts of Europe, and belongs to the second group of balsams, those containing cinnamic acid.

The storax of commerce comes from Asiatic Turkey. The balsam exudes from incisions through the bark, and when somewhat hardened constitutes the balsamic substance sold by druggists under the name of storax. The bodies thus denominated are, however, very numerous, and of variable character and composition; they are for the most part artificial compounds, utterly dissimilar from the genuine balsam.

Real storax is extremely rare. It occurs in compact masses, of a very fragrant odour and of a rich brown colour, interspersed with white tears, whence the name *amygdaloid styrax*. It was formerly imported enveloped in a monocotyledonous leaf, under the name of cane or reed styrax—*styrax calamita*. In the drug market, two substances are generally met with bearing the name of storax; one of them is

called *styrax liquidus;* it is usually of a black, brown, or grey colour, and generally has a disagreeable odour, more resembling that of coal-tar than of the balsam. The other is usually labelled *styrax calamita*, and is a black, brown, or purplish article, either pulverulent or granular, or in the form of agglutinated lumps. Some of it is said to consist of pulverized decayed wood, imbued with a little liquid storax; other samples appear to be fine sawdust, impregnated either with coal-tar or something analogous, and not bearing the remotest similarity to the genuine balsam.

SIMON was the first to show that the acid found in storax, and which had always been taken for benzoic acid, possessed all the properties of cinnamic acid; and an analysis of the silver salt by MARCHAND proved the acid to be the latter.

Storax, as well as the tree producing it, was known to the ancient Greeks and Romans. It is alluded to by HIPPOCRATES, THEOPHRASTUS, and PLINY.

OPAQUE LIQUID STORAX.—This is imported from Trieste in casks or barrels, holding about 4 cwts. each. It is opaque, of a grey colour, and is of the consistence of birdlime. It has the odour of storax, but frequently intermixed with a feeble smell of benzol or naphthalin.

The substance met with in the shops, and sold to perfumers under the name of strained storax—*styrax colatus*—is prepared from liquid storax, by heating it until the water with which it is usually mixed is evaporated and then straining it. During the process, it evolves a very fragrant odour. The impurities are stones, sand, *et cetera.*

PELLUCID LIQUID STORAX.—*Storax liquide pur*, GUIBOURT.—This substance is a pellucid liquid, having the consistence and tenacity of Venice turpentine, a brownish-yellow colour, a sweetish storax or vanilla-like odour, entirely different from that of liquidambar. A few particles of bran or sawdust are commonly intermixed with it. By keeping, it yields a white and acid sublimate on the sides of the bottle which contains it.

All the storax imported into this country comes from Trieste. The following are the results of REINSCH's analyses of styrax calamita:—

	1. Styrax calamita.	2. Brown granular.	3. Reddish compact.
Volatile oil,	?	0·5	0·4
Resin,	41·6	53·7	32·7
Sub resin,	?	0·6	0·5
Benzoic acid,	2·4	1·1	2·6
Gum and extract,	14·0	9·3	7·9
Matter extracted by potassa,	15 0	9·6	23·9
Woody fibre,	22·0	20·2	27·0
Ammonia,	traces	stronger traces	strongest traces
Water,	5·0	5·0	5·0
Styrax calamita,	100·0	100·0	100·0

The volatile oil was obtained by digesting the distilled water of storax with ether. The *solid* oil was white, crystalline, and fusible; its odour was agreeable, its taste aromatic and warm. The *fluid* oil had a less penetrating odour.

SIMON found liquid storax to consist of styrol, cinnamic acid, styracin, a soft and a hard resin.

Storax is used in medicine, and is called a stimulating expectorant. In its operation it is closely allied to balsam of Peru and benzoin, but it is less powerful than the latter. It is used also as a detergent in the form of ointment.

LIQUIDAMBAR is obtained from the *liquidambar styraciflua*, a tree which grows in Mexico, Louisiana, and Virginia. There are two varieties, the one thin like oil, and the other thickish like turpentine. The former is the balsam as it runs from the tree; the latter is the form it assumes after exposure to the air. It is transparent, amber-coloured, has an agreeable and powerful smell, and an aromatic taste, which is somewhat pungent in the throat. Boiling alcohol dissolves it almost entirely. It contains a good deal of benzoic or cinnamic acid, some of which effloresces when the resin hardens, as it does with keeping.

TOLU BALSAM is the produce of *Myrospermum toluiferum*, a tree growing on the mountains of Tolu and Turbaco, and on the banks of the Magdalena, between Garapatas and Monpox. It exudes during the heat of the day from incisions in the bark: and is imported chiefly by way of New York and Jamaica, generally in tin canisters, but sometimes in earthen crocks and in calabashes. On its arrival it is soft and tenacious, but gradually hardens; it is translucent, brown, very fragrant, and has a sweetish taste, softening between the teeth. When heated, it fuses and takes fire, diffusing an agreeable odour. The tree which yields the balsam of Tolu was formerly called *Toluifera balsamum.* RICHARD having carefully investigated the characters of the genus Toluifera, found that, with the exception of the fruit, they were identical with those of the genus now called *Myrospermum;* and as RUIZ states that the balsams of Tolu and Peru are obtained from the same tree, the *M. peruiferum* has been adopted by several writers, and by the London College, as the source of both balsams. RICHARD made a distinct species of the tree yielding the balsam of Tolu, and it is now called *M. toluiferum.*

Tolu balsam contains a volatile oil, cinnamic acid, and two resins; the one soluble, the other insoluble in alcohol. The volatile oil is tolene (KOPP) and is isomeric with oil of turpentine, $C_{10}H_{16}$. On distilling Tolu balsam, MUSPRATT remarks:—There passes over at first aqueous vapour, and when the temperature is sufficiently elevated, a large quantity of benzoic, with a slight admixture of cinnamic acid, which solidifies immediately in the recipient into a white crystalline mass. When the fluid distilling over no longer solidifies, the receiver is charged; a yellow liquid condenses. The crystalline mass collected in the first receiver contains likewise a large quantity of the same liquid, which can be separated by mere distillation with water. KOPP states that the benzoic acid is a product of decomposition, and does not exist in the balsam itself.

Balsam of Tolu is frequently adulterated with common resin. To detect this, pour sulphuric acid on the balsam and heat the mixture. The balsam dissolves to a cherry-red fluid, without evolving sulphurous acid, but with the escape of benzoic or

cinnamic acid, if no common resin is present; on the other hand, it foams, blackens, and much sulphurous acid is set free, if it is thus adulterated.

PERU BALSAM.—*Balsamum peruvianum, Balsamum indicum.*—There are three varieties of this balsam, viz:—White Peru balsam, dry Peru balsam, and black Peru balsam. Of these, the black only has any practical applications. They are alike the produce of the *Myroxylum*, or *Myrospermum*, a tree growing on the coast of San Salvador, Central America.

The earliest mention of Peru balsam is made by Nicolas Monardes in 1565; he calls it simply *bal-*

Fig. 1.

samo, and says that it is the produce of a tree growing in New Spain, and called by the Indians *xilo*. He mentions two modes of procuring the balsam—one by incision into the rind of the stem, the other by boiling the branches in water; and he afterwards notices its physical properties and valuable medicinal qualities.

Francisco Hernandez, a Spanish physician and naturalist, who resided from the year 1593 to 1600 in Mexico and New Spain, notices four balsam trees: one called *Hoitziloxitil*, a second named *Ilnaconex*, and a third denominated *Maripenda*, and the fourth found in the province of Tolu. Of these four, the first appears to be identical with the tree which yields the so-called balsam of Peru; a copy of Hernandez's drawing of it is subjoined—Fig. 1.

Hernandez states that the Indian balsam tree—*arbor balsami Indici*—is called by the Mexicans *hoitziloxitil*, because it abounds in resin. He describes it as being of the size of a lemon tree, and having leaves which are larger than those of the almond, but rounder and more acuminate. The flowers are yellow, and are placed on the summits of the branches. The seeds are whitish, oblong, somewhat contorted, and lodged at the extremity of the oblong shells or fruits, which are longer and broader than the leaves. The tree, he says, was cultivated by the Mexican kings in the Hoaxtepec gardens. He also states that the seeds yield by pressure an oil, which resembles in flavour and odour that obtained from bitter almonds and peach kernels.

After the death of Linnæus, who had always been particularly anxious to ascertain the plant which yields this balsam, Mutis sent to the younger Linnæus specimens of the leaves and flowers of a plant which, he said, grew in the warmest provinces of South America and yielded Peruvian balsam; subsequent investigation has, however, proved this statement to be erroneous, as will be seen further on. A description of this plant, to which the name of *Myroxylon peruiferum* was given, was published in the *Supplementum Plantarum.* Fig. 2 is a sketch of the leaflets of *Myroxylon peruiferum.* The figure is about one-third the natural size of the leaf.

The first accurate botanical description of the tree which really yields balsam of Peru was given by Ruiz, in 1792, in his *Quinologia.* Ruiz says the tree is known in Peru under the name of *Quinoquino*, and he calls it Myroxylon peruiferum, considering it to be identical with the *M. peruiferum* sent by Mutis to the younger Linnæus. This, however, is an error, Ruiz's plant being, according to Kunth and De Candolle, a distinct species from that of Mutis. Ruiz states that the tree grows in the mountains of Panatahuas, in the forests of Puzuzu, Muna, Cuchero, Paxatin, Pampahermosa, and in many other countries near the river Maranon, in low, warm, and sunny situations; but the Indians of these places do not collect the balsam.

Fig. 2.

Ruiz says the balsam of Quinoquino is procured from incisions made in the tree at the beginning of spring, when the showers are gentle, frequent, and short; it is collected in bottles, where it keeps liquid for some years, in which state it is called *white liquid balsam.*

In 1823 appeared the sixth volume of Humboldt, Bonpland, and Kunth's *Nova Genera et Species Plantarum.* In this work the plant of Ruiz, called by him *M. peruiferum*, Linnæus, is denominated *Myroxylum pubescens*, and the designation *Myroxylum*

peruiferum is retained for the plant sent by MUTIS to LINNÆUS. These distinctions have been adopted by DE CANDOLLE, who, however, has followed JACQUIN, and designated the genus *Myrospermum*, instead of *Myroxylon* or *Myroxylum*. But it is most unfortunate that the specific name *peruiferum* should be retained for a plant which does not yield the so-called Peruvian balsam.

In 1834 M. BAZIRE stated that the so-called balsam of Peru was not the produce of Peru, but of the coast near Sonsonate. He forwarded some of the fruit to Europe, when it proved to be that of the *Myrospermum pubescens* of DE CANDOLLE, and not that of *Myroxylum peruiferum*.

The uncertainty which existed respecting the origin of balsam of Peru was finally cleared up by Mr. SKINNER, who procured for Dr. PEREIRA specimens of the tree and balsams from Central America, and furnished him with the following facts:—

1. The tree which yields the black and white balsams of Peru is the species described and figured by RUIZ, the *Myrospermum pubescens* of DE CANDOLLE.

2. Black balsam, the balsam of Peru of commerce, is obtained by incision from the stem.

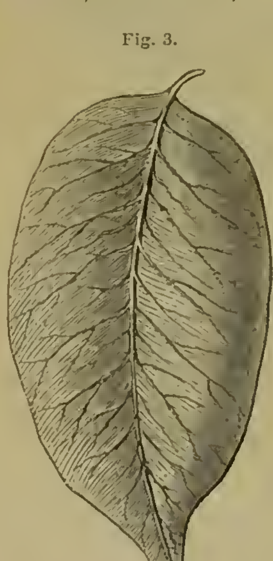
3. The white balsam is procured from the fruit by pressure.

4. Both these balsams are exclusively obtained from the so-called Balsam Coast in Central America.

Dr. PEREIRA, however, doubts whether the *Myrospermum* of Sonsonate, from which balsam of Peru, white balsam, and balsamito, are obtained, is identical with that figured by RUIZ, and which, according to both KUNTH and DE CANDOLLE, is *M. pubescens*. He, therefore, designates the plant the *Myrospermum of Sonsonate*.

The branches are terete, warty, but otherwise smooth, ash-coloured, or ash-brown.

Fig. 3.



The leaves are alternate, petiolate, and imparipinnate. The common petioles appear to the naked eye devoid of hairs, but when examined by the microscope are found to be covered with a few short ones.

The leaflets are from five to eleven, alternate with short petioles. Fig. 3 represents one of these leaflets in its natural size. Exclusive of foot-stalk, their length varies from about 2 to $3\frac{1}{2}$ inches; and their greatest width from 1 to $1\frac{1}{2}$ inch. The most usual size is 3 inches in length, and $1\frac{1}{4}$ to $1\frac{4}{10}$ths of an inch in breadth. Their general shape is oblong or oval oblong, in some cases ovate. They are round, or very slightly tapering, not cordiform at the base. Superiorly they contract abruptly into an emarginate point. To the naked eye the partial petioles and mid-ribs appear devoid of capillæ, but when examined by the microscope short lymphatic hairs, having a glossy or resinous appearance, are distinctly visible on them; and the partial petioles appear somewhat rough from transverse rugæ. The leaflets are elegantly marked by rounded and linear pellucid spots; the lines being usually parallel with, or in the direction of, the primary veins. To see the spots, the leaflets must be held up against a strong light, and examined by a magnifier.

The fruit is a one-celled, one-seeded, winged, indehiscent pod, called by some a samara, by others a samoroid legume. The fruit-stalk is naked at the base, but is amply winged superiorly. The fruit, including the winged foot-stalk, varies in length from about 2 to 4 inches; the usual length is $3\frac{1}{8}$ or $3\frac{1}{4}$ inches. At the peduncular extremity the fruit, or rather its winged foot-stalk, is rounded or very slightly tapering, unequal-sided; at the summit it is enlarged, turned, and rounded with a small point—the remains of the style—at the side. The mesocarp is fibrous; but immediately exterior to the endocarp it contains, in receptacles, a yellow oleoresinous or balsamic juice, which by age hardens and resinifies. RUIZ, KUNTH, ENDLICHER, and DE CANDOLLE, describe this juice as immediately surrounding the seed, and being between it and the lining—endocarp—of the shell; but this is a mistake, it is exterior to the endocarp.

The principal part of the balsam resides in the two receptacles or *vittæ*, one placed on either side; but if a transverse section of the fruit be examined by the microscope, numerous receptacles of the more or less dried balsam are perceived in all parts of the mesocarp. In the two larger receptacles, the balsam is usually found in the liquid state; but sometimes the walls of the receptacles are lined with the crystallized balsam (the *myroxocarpin* of STENHOUSE). That the balsam resides in the mesocarp, and not in the cavity of the fruit, is proved by the cross section, which shows that the paries of the cavity of the fruit is continuous with the two sutures. The seed lies loose and dry in the cell of the pericarp, and is covered by a thin, white, membranous coat—testa. The cotyledons are yellowish and oily, have an agreeable odour, like that of the tonka-bean or melilot, and a bitter taste, somewhat resembling that of bitter almonds. By digesting the seeds in ether, a tincture is obtained which yields on evaporation a very agreeable-smelling, amber-coloured, soft extract, the odour of which resembles that of the cotyledons. Fig. 4 is a cross section of the fruit and seed, magnified:—*a a*, epicarp; *b b*, mesocarp; *c c*, endocarp; *d d*,

Fig. 4.

large vittæ, or lacunæ, containing balsam; *e e*, cotyledons.

In the annexed sketches, Fig. 5 shows a leaf-bearing branch of the Myrospermum of Sonsonate, about one-third the natural size; Fig. 6, a fruit-bearing

Fig. 5.

branch; Fig. 7, vertical section of the fruit; Fig. 8, lateral section of the fruit, showing the seed *in situ*.

Central America is the country of the Myrospermum Sonsonate. It grows on the Balsam Coast—between 13° and 14° north latitude, and 89° and 90° west longitude—in the state of Salvador, where the black and white balsam are exclusively obtained from

Fig. 6.

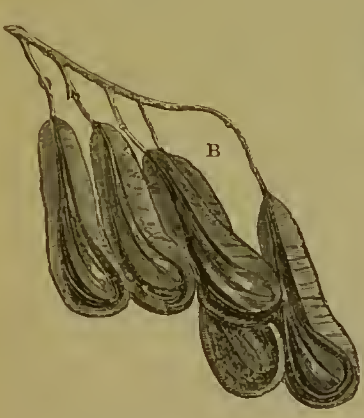


Fig. 7.

Fig. 8.

it. Hernandez gives Panuco as one of the places where it grows; and Clavigero states that it is common in the provinces of Panuco and Chiapan.

Various medicinal products are obtained from the tree. By making an incision in the trunk of it, a liquor exudes called the "black balsam," an admirable remedy for effecting the speedy cure of wounds of every description: from the flowers the "spirit of balsam" is made; the seeds or nuts produce the "oil of balsam," an excellent anodyne; and the capsules yield the "white balsam."

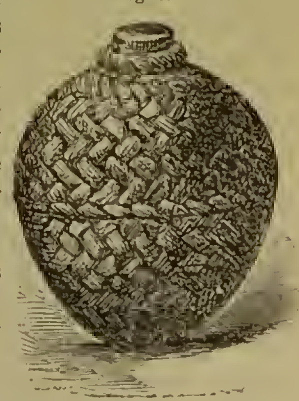
From these simple balsams the "tincture" or "essence of balsam" is extracted. It is generally termed *balsamito*, and was a discovery of Don Jose Eustaquio de Leon, director of the mint in Guatemala, who published a description of the many virtues of this peculiar medicine. The only medicinal products of the tree are, black balsam—commonly called balsam of Peru—white balsam, and balsamito.

White Balsam of Peru.—This balsam is quite neutral to test paper, and has a peculiar agreeable odour like melilot. It was observed by Stenhouse that when white Peru balsam is digested in ordinary alcohol, a considerable portion readily dissolves; and when the clear extract is allowed to repose for a day, it deposits a quantity of large white crystals, to which he gave the name Myroxocarpin. They retain a good deal of adhering resinous matter, which can be removed by digestion with a little animal charcoal and repeated crystallizations from hot alcohol. When pure, they are hard and brittle, colourless, tasteless, scentless, and form broad thin prisms, more than an inch in length. Myroxocarpin is insoluble in hot and cold water; but is readily dissolved by hot alcohol and ether. To these crystals Stenhouse has applied the name. The formula of Myroxocarpin is $C_{48}H_{70}O_{6}$. It does not unite with either acids or alkalies, and is not decomposed by a solution of potassium or sodium hydrate.

Myroxocarpin fuses to a transparent liquid, which does not crystallize on cooling; but when redissolved in hot alcohol it reassumes the crystalline form on evaporating the solution. By chlorine it is converted into an amorphous resin. Heating with nitric acid decomposes it into oxalic acid and an uncrystallizable resin.

The Sonsonate or St. Salvador white balsam—*balsamo blanco*, is often confounded with the balsam of Tolu. White balsam is obtained at Sonsonate by pressure, without heat, from the interior of the fruit and seed. It is imported in globular earthen jars, surrounded by a kind of plaited matting—Fig. 9—closed by an earthen stopper. The jar inclosed in the matting is about 1 foot high, and 10½ inches in diameter, and contains about 20 lbs. of balsam, which is partially concreted or crystallized on the sides. When removed from the jar, and put into a white glass bottle, it closely resembles in appearance strained American or Bordeaux turpentine. It is semifluid, or a soft solid, and by exposure becomes

Fig. 9.



firmer. It is quite devoid of the fragrant cinnamon odour of the black balsam of Peru and balsam of Tolu.

According to SKINNER'S account, the balsam is obtained thus:—A fire is made around, but at some little distance from the balsam tree; the bark is then cut, and a stick slipped in between it and the wood, so as to partially separate these two parts of the stem from each other. By working the stick about, somewhat in the manner of a pump-handle, the balsam, aided by the heat, exudes and is absorbed by rags.

The only purification to which balsam of Peru is subjected in England is mechanical; that is, the balsam is, by standing, allowed to separate from the water and other impurities, and is then drawn off.

M. SARAVIA, of Sonsonate, having questioned the Indians respecting the production of balsam, states that the method used to extract the balsam from the trees is to make several incisions, over which pieces of old cloth or rags are placed for the absorption of the juice; when they are well soaked, they are put in water to boil, until they have discharged the greatest part of the imbibed balsam. The liquid is then allowed to settle sufficiently, until the water rises, leaving the balsam at the bottom; next, the upper stratum is carefully poured off, and the balsam put into gourds, although at this time it is not very pure. The rags are then put into "redes," little bags of cords, which are strongly twisted to wring out any remaining balsam into the gourds. When purchased, it is necessary to clean it again, because it still contains water and other impurities, which some Indians will mix with it to gain greater weight.

Black Peru Balsam; the Sonsonate of St. Salvador; black balsam.—This is the balsam of Peru of commerce—*Balsamum Peruvianum*, Latin. At Sonsonate it is termed *black balsam—balsamo nigro.* It is sometimes denominated the *black* or *liquid balsam* of Peru. Sonsonate or St. Salvador black balsam of commerce (the balsam of Peru of the shops) is exclusively the produce of the Balsam Coast, which extends from the Ajacutla to the Port Libertad on the Pacific side of Central America.

The varying methods of obtaining black Peruvian balsam causes great differences in the product; and besides this the various kinds of Myrospermum used for yielding the balsam, the higher or lower degree of heat employed in its preparation, all contribute to vary the quality obtained.

SKINNER says the method employed by the Indians of Central America for extracting the black balsam from the tree is as follows:—They begin by making an incision from 2 to 2½ inches broad, and from 3½ to 4 in length; they then raise the bark from the living wood, and afterwards apply there pieces of cotton rags, after having heated the tree by surrounding it with a brisk fire for a short time. When they tap the tree for the first time, they make the incision rather more than a yard above the ground, and when the liquor ceases to ooze out, they make a second incision by the side of the first one, and in the same manner, but a little higher up; and thus they continue making new incisions as fast as they become exhausted around the tree. In the course of ten or twelve days the rags become thoroughly impregnated with a thick olive-brown liquid; they are then withdrawn, and subjected to a fresh process. The rags saturated with the balsam are collected together and placed in an earthen vessel, called olla or pot, with some water, and boiled for five or six hours. During this operation the balsam detaches itself, and so long as the boiling continues mixes with the water; but as soon as the liquid becomes cold, the balsam, being much heavier, settles, and the water floats over it; hence it is easy to separate them from each other. Before the water cools, the cotton rags are removed; but as they still contain a certain quantity of liquid, they are subjected to a more forcible pressure by means of a small machine, made with pieces of wood, cords, and tourniquets. Lastly, they collect all the balsam extracted from these rags, after subjecting them to pressure for several days; pour off the water, and put the balsam, which has now become dark and liquid, into a calabash, for the purpose of carrying it to market. The balsam which flows from the tree always contains a considerable quantity of water, and hence the necessity of boiling this liquor after it has been extracted.

Balsamum Peruvianum nigrum is generally exported from Sonsonate and Ajacutla, Central America, in jars, after being deprived of its water, mucilage, and salt (which is generally effected in a tub); and is transferred to Europe in tins. A considerable quantity of water is still retained and commonly separates in the course of the voyage. In a fresh state the balsam is greenish and more fluid than after having been kept for some time, when it becomes a deep brown, opaque in the mass, but in thin layers transparent and of a golden red colour.

The characteristics to be noted in the judging of its genuineness are:—Its agreeable odour resembling that of vanilla, complete miscibility with alcohol, by which the absence of fixed oil is shown, and its suffering no diminution of volume after mixing with water, proving that there is no spirit present. A sign of its purity, according to MUSPRATT, is that 1000 parts of it should saturate 75 parts of crystallized potassium carbonate, it having an acid reaction.

Black Peru balsam is viscid, but not glutinous; on exposure to air its viscidity increases, but it does not solidify. Its taste is peculiarly bitter and irritating. When heated, it takes fire and burns with a smoky flame. It mixes with absolute alcohol in all proportions, but deposits a flocculent precipitate on standing. On distillation with water, black balsam of Peru yields cinnamic acid. Sulphuric acid converts it into a thick red mass, with evolution of sulphurous acid. When two volumes of balsam of Peru are heated with three volumes of solution of potassium hydrate, 1·3 specific gravity, two layers of liquid are produced: the lower consisting of cinnamic acid, resins, and various colouring matters; and the upper of a brownish oil, which is termed oil of balsam of Peru.

Balsam of Peru was first analyzed by STOLTZE, who found:—

	Per Cent.
Brown slightly soluble resin,	2·40
Brown resin,	20·70
Oil—cinnamein ($C_7H_7,C_9H_7O_2$),	69·00
Cinnamic acid ($C_9H_8O_2$),	6·40
Extract,	0·60
Loss and moisture,	0·90
	100·00

FREMY describes the balsam as consisting of varying quantities of cinnamein or styracin ($C_7H_7,C_9H_7O_2$), an isomeric crystallizable substance, metacinnamein, cinnamic acid ($C_9H_7O_2$), and resin. The various components are separated by dissolving the balsam in absolute alcohol and adding alcoholic potassium hydrate solution, which precipitates the resin. The cinnamein is next precipitated by adding water, and purified from resin by solution in petroleum, and evaporation. The remaining solution will contain cinnamic acid only.

Cinnamein ($C_7H_7,C_9H_7O_2$), or cinnamate of benzyl, is a volatile oil of a feeble, rather pleasant odour, but a sharp aromatic fatty taste; it produces grease spots on paper. It is nearly insoluble in water, but dissolves readily in alcohol. It absorbs oxygen from the air, and acquires thereby a rank odour and an acid reaction. Its specific gravity at 60° Fahr. (15°·5 C.) is 1·0975.

Balsam of Peru is frequently adulterated with castor oil and copaiba balsam, &c. Fixed oils are detected by their remaining insoluble in alcohol; volatile oils can be distilled from the aqueous mixture of the balsam; sugar and like bodies are discovered by the diminution in volume which the adulterated balsam evidences when shaken up with water.

Considerable variations occur in the specific gravity of Peru balsam, which must not be altogether overlooked. It usually varies between 1·14 and 1·16; but when sophisticated with as much as 25 per cent. of castor oil, it is much lower.

To detect copaiba balsam, the substance is to be heated in a small tube retort, until a few drops of a yellow oily liquid have passed over, which takes place at a temperature of 374° Fahr. This distillate is acid, and soon deposits crystals of cinnamic acid. If the balsam used was pure, it solidifies completely; but when adulterated with copaiba, the crystals float in copaiba oil. The distillate is then to be saturated with caustic potassa, and a solution of cinnamate removed by means of blotting-paper. The drops of oil which are then left mix quietly with iodine if the balsam was pure, but cause a violent action in the presence of copaiba.

An expert chemist can detect the presence of copaiba by its smell; in general, the purity and strength of the vanilla-like odour of the Peru balsam, and its perfect transparency, are some proofs of its goodness.

Black balsam of Peru is used in confectionery, in lozenges and chocolate, as a substitute for vanilla; in perfumery it is employed to scent pomatums, sealing-wax, &c. The once celebrated "Pomade Divine" contained a large quantity of balsam of Peru. One of the best recipes, according to URE, was:—

Fine olive oil,	18 ozs.
Balsam of Peru,	1 oz.
Aris root,	6 drachms.
Storax,	1 drachm.

This mixture, with some bruised nutmegs and cinnamon, was macerated in a water bath for three hours and then filtered. The resulting aromatic oil was mixed with 6 ozs. of white wax and 1 oz. of spermaceti; these were mixed together, and a few drops of the essential oils of nutmegs, cinnamon, and cloves added.

In medicine balsam of Peru is used as an application to wounds, and also as an internal remedy.

Dry Peru Balsam—Balsamum peruvianum siccum, Opobalsamum siccum.—This substance is said by WEDDELL to exude spontaneously from the myroxylum, and to harden as it comes in contact with the air. FROMSDORFF gives its composition as:—

	Per Cent.
Cinnamic acid,	12·0
Volatile oil,	0·2
Resins,	88·0
	100·2

Its colour is reddish yellow; it is hard, transparent, smells like vanilla, melts when heated, and burns with a smoky flame.

BEER—*bière*, French; *bier*, German—the spiritnous liquor made from any farinaceous grain, but more especially from barley. The grain is first malted and ground, then its soluble part extracted by hot water. This extract or infusion is concentrated by boiling in caldrons, and hops, or some other plant of an agreeable bitterness, added. The liquor is then allowed to ferment in vats. The term beer is also applied to fermented liquors made from ginger, spruce, and molasses, as well as to that procured from malt and hops.

In this country beer is of different degrees of strength, and is denominated small beer, ale, porter, brown stout, &c., according to the quantity and nature of its ingredients. In the United States beer is the name given to fermented liquors made of various materials besides grain. When a decoction of the roots of plants forms part of the composition, it is called "spring beer," from the season in which it is made. There is also "root beer."

In the time of TACITUS, whose treatise on the manners of the Germans was written about the end of the first century of the Christian era, beer was their common drink: PLINY mentions it as being used in Spain, under the name of *cælia* and *ceria;* and in Gaul, under that of *cerevisia;* he then proceeds to explain that almost every species of corn has been used for the manufacture of beer.

These observations are corroborated by other ancient authors. The *cerevisia* of PLINY evidently takes its name from *Ceres*, the goddess of corn—philologists doubting whether it ought not to be written *cererisia*. PLAUTUS more minutely calls it *Cerealis liquor;* that is, liquor used at the solemn feasts in honour of that goddess—the *harvest home;* and both he and COLUMELLA—a famous writer on agriculture, a contemporary of CLAUDIUS, and whose

work is therefore coeval with the invasion of Britain by that emperor—called this liquor *zythum*, which if traced back to its Greek origin is interpreted, "drink from barley."

In Europe beer is usually made from barley; in India from rice; in the interior of Africa, according to MUNGO PARK, from the seeds of the *holcus spicatus*, a species of couch grass.

In the brewing of beer, the first process of importance which comes under notice is that of malting. Ere this can be proceeded with, however, the grain on which to operate must be chosen, and it is hoped the few following remarks will be found of service, more especially to the inexperienced.

SELECTION OF BARLEY.—The barley most suitable for conversion into malt grows in large hedgeless tracts of light calcareous soil, and crops, excellent in quality, also thrive on rich loam. Much, however, depends upon the seed; the best possesses a bright, clean, thin, wrinkled husk, tenaciously adhering to a plump, round, well-fed kernel, which, when bruised, appears chalky and sweet, with a germ full, and of a pale yellow colour. If the barley breaks with a flinty fracture it must be rejected. The barley most profitable for malting is the "rath," or early ripe, which matures several weeks before other sorts, and is that which agriculturists ought to select, not only on account of its forwardness, but also because it makes superior malt, in consequence of the thinness of its skin and the lusciousness of its nature. Barley is not in a proper condition for malting until it has sweated and seasoned in the stack; if stacked too damp it will generate so much heat as to destroy the germ. The maltster should be careful to avoid mixing old and new barley, as these never grow evenly or simultaneously on the malting floors, and consequently do not work well together.

Adept brewers, from their long experience, know the best kinds of grain to select.

MALT AND MALTING.—Oats, peas, beans, maize, buckwheat, and common wheat, are all capable of being malted, and have been experimented upon, but barley is almost exclusively used for this purpose.

The heaviest grain is recommended, as, if in good condition, it gives malt of corresponding gravity.

What is here technically understood by "heavy malt" is, that it shall be tender and friable throughout, and without hard ends. Perfect malting is not always attainable, even with the best skill and management, and it would on this account be improper to pass lightly or carelessly over such an important subject.

Malt may be very heavy and yet too hard properly to bear the name of malt; and inexperienced brewers may be greatly deceived, unless they have sufficient knowledge to discriminate between the several varieties sent into the market.

If the extract from the malt is deficient, in comparison with that of the best quality, it is also deficient in fine flavour.

The utmost skill is required to produce a malt of abundant sweetness and friability: when these are attained it will never be too heavy.

If the brewer is also a maltster, as he ought to be, both in knowledge and in practice, he can procure malt any colour he pleases; but even if he be not, there is no difficulty in obtaining malt of any peculiar tint or flavour he desires.

The whole process of malting is comprised under four successive operations: "Steeping," "Couching," "Flooring," and "Kiln-drying."

The excise regulations press with great severity upon the maltster. Malting is regulated by the Act 7 and 8 George IV. cap. 52, and 11 George IV. cap. 17. The steeping vessel must be of a certain specified size and construction, and must have been approved of by the excise office. As URE points out, the law allows the maltster no option, though from the uncertain character of grain it might be inferred that the process of steeping would be left to the judgment of the maltster, who would determine, according to his experience and the nature of the resulting phenomena, when the grain had been steeped long enough in the water. Whether the grain be old and dry or new and moist, "maltsters are required to keep their corn or grain covered with water for the full space of forty hours, under the penalty of £100." Nor will any change occurring in the appearance of the grain, and seeming to require its immediate removal, justify or excuse the maltster in so doing, unless indeed he shall have anticipated the occurrence by giving notice of his intention to do so in his original notice "to wet" (which must date twenty-four hours previous to the commencement of that operation), and give the day and hour of the day for beginning the "steep," all under the usual penalty of £100. Nor may he "begin to wet at any other time than between the hours of eight in the morning and two in the afternoon," under a penalty of £100; nor may he take corn or grain from any cistern at any other time than between the hours of seven in the morning and four in the afternoon. To empty corn or grain out of any cistern, until the expiration of ninety-six hours from the time of the last preceding emptying of any cistern in the establishment, involves a penalty of £200; and the same infliction occurs "if the grain be not emptied out of all such cisterns at one and the same time, or within three hours after the clearing of the first cistern was commenced.

Maltsters are not to mix, either on the floor or kiln, any corn or grain of one wetting with corn or grain of another wetting, under a penalty of £100.

The power of loosening or compressing the grain when on the couch, according to its temperature, would evidently much improve the formation of malt, but here again the maltster is restricted; the grain has been gauged in the steep, and again on the "couch," or place where it is laid to germinate, and if the maltster should any way compress it, so as to diminish its bulk, he incurs a penalty of £100. Again, if too little water or too much water is absorbed by the grain during steeping, no subsequent manipulation of the grain is allowed unless the grain has been in the steep for fifty hours, when, after six days (144 hours), the maltster may sprinkle

it with water. If the grain has been at first insufficiently wetted it desiccates about the end of the third day, ceases to germinate, evolves a sickly odour, and becomes mouldy, so that the relief afforded by the law is more in appearance than reality. URE states that such is the great urgency for the sprinkling on the third day, that "it is an undeniable fact that, in spite of the heavy risk incurred (£200), maltsters do almost invariably sprinkle their floors at about this period."

The excise officer makes three separate ganges of the grain—1, in the steep; 2, on the couch; 3, on the floor: of these he must select the largest for charging duty upon. Thus, if he finds that "the cistern or couch gauge exceeds the floor gauge, then the best cistern or couch gauge will be the charge; but if that be less than the floor gauge then the floor gauge will be the charge." Any accident or loss arising after the "steep" is thus thrown wholly upon the maltster; and the carelessness, malice, or ignorance of common workmen may at any time subject the honest maltster to charges of dishonesty and penal inflictions.

The chemistry of malting has been already described at page 58 (ALCOHOL). We give here Dr. GRAHAM's description of the botanical change. Inside the grain, or rather "caryopsis," of barley is a large amount of starchy matter, which is termed by botanists "albumen." At the base of this starchy matter is the young embryo of the future plant. Now when the seed of the barley is moistened, provided there is a moderate degree of heat, it will gradually swell, presently the skin will burst, and at the lower end the radicle or small rootlet will gradually protrude. After that has taken place there is from the upper surface of the embryo a gradual prolongation of the plumule of the young plant.

The important points about the process to consider are the following:—First of all, the young seed gets warm, gives out carbonic acid, and the so-called albumen, or starchy matter of the cotyledons, is gradually used up and consumed; in other words, the young plant is in this stage of its existence really not yet hatched, but is still, from a chemical point of view, very much like the chick in the ordinary egg; and GARTNER, the physiologist, who first of all gave the term albumen to the starchy matter surrounding the young embryo, was perfectly right from a physiological point of view to call it so, since it serves the same functions which the white of an egg does to the embryo inside a hen's egg. It is a store of food laid up there by the parent. It gradually diminishes, and as it diminishes the young plant or the young animal gradually increases in bulk. Finally, the young plumule bursts through the upper end, aud in process of time comes in contact with the atmosphere.

In this process all that is needed is a small amount of moisture and a small amount of heat, because barley grows well even in the north of Scotland.

Steeping.—As stated above, steeping is to cause the grain to absorb the necessary amount of moisture to start the germination, which is requisite before its starchy matters, the "albumen," can be converted naturally into glucose.

The steeping is usually performed in large wooden or stone cisterns, into which the grain to be malted, already screened down and nicely levelled, is shot; it must be charged with liquor to 6 or 7 inches above the barley, and although the grain has been well cleaned, there may be some light grains and other matters floating on the surface of the liquor; these must be skimmed off, since if allowed to remain they would impair the quality of the malt, and also the flavour of the beer made from it. However, the improved cultivation of the soil, and the new varieties of barley, have of late years done away with the necessity of skimming.

In consequence of the absorption of moisture, the grain swells about one-fifth in bulk, and increases about 50 per cent. in weight, 100 lbs. of barley thus becoming 150 lbs.

The object of steeping is to expand the farina of the barley with humidity, and thus make the seed fit for germination, when subsequently exposed to the air. Too much steeping is injurious, because it prevents the germination at the proper time, in consequence of the air being excluded whilst the superabundance of water is spontaneously evaporating; it is hurtful, also, on account of its extracting a portion of the saccharine matter. The maceration is known to be complete when the grain may be easily perforated with a common needle, and is swollen to its full size; or if a barley-corn, when taken between the thumb and fingers and pressed, sheds its flour upon them, it is ready; but if it continues entire, or its substance exudes as a milky juice, it is either, in the first instance, not sufficiently steeped, or, in the latter, the steep has been too long continued, and the grain is spoiled for germination.

In warm weather it sometimes happens that, before the grain has sufficiently swelled, the water becomes acid, from the production of acetic or lactic acid; this can be ascertained by testing with blue litmus paper, and may be immediately remedied by drawing off the foul liquor by means of the tap at the bottom of the cistern, and replacing it with fresh cold water. No harm is done even if the water be renewed three times during one steep.

The time of steeping, which varies according to the temperature and other circumstances, requiring in winter a longer and in summer a shorter period, is reckoned technically by the term "tide," each being of twelve hours' duration. In summer from forty to forty-eight hours is sufficient time for good grain. In winter it may extend over five and a half or six tides, from the time the liquor is put into the cistern to the time of letting, sixty-six or seventy-two hours; at others it will cease to swell much sooner, but, as a general rule, the grain is permitted to lie in the cistern until it will no longer swell, after which, the liquor being drawn off, it is left to drain for six hours before it is emptied into the couch. If now the skin, which is somewhat loosened, be partially removed from the kernel, and the two ends are slightly pressed, the latter will be seen to be partly separated.

Any practical farmer would say that the worst way to make seed germinate and grow well is to drown it; but this is exactly what is done, and by law obliged to be done, by the maltster. In the fifty hours during which the barley is in steep the following changes take place:—

In the first place the grain swells much as it would in the soil; it absorbs water, which dissolves some of the albuminous matter, some of the so-called diastase, and owing to the solution of the albuminous bodies a change is set up, and a degradation or a breaking down of the albuminous matter goes on; and following on that degradation there is at the same time a conversion of the insoluble starch (which is of no use to the young plant, for it requires soluble food) into soluble dextrine and also glucose.

As time goes on the water in the steep gradually dissolves out, not only the colouring matter from the husk, but also some of the soluble albuminous matters, and at the same time some of the soluble dextrine and glucose which is formed. The water becomes darker and darker in colour, it froths when poured from one vessel to another, and then is set up a slow putrefactive fermentation, producing in warm weather a most unpleasant smell.

In Bavaria steeping is carried to a still greater extent, for the maltster soaks it for at least three days, renewing the water constantly.

In Bohemia the plan pursued appears to be more scientific. The grain is steeped for twenty hours, taken out, allowed to dry, and after about twenty-four hours returned to the steeping cistern for from six to eight hours, according to the season.

The Couch,—The water being drawn off, and a fresh quantity occasionally passed through, to separate the grain from any slimy matter which may have been generated, it is laid upon the stone flag-floor of the couch in square heaps, from 12 to 16 inches in depth, and left in that position for twenty-four hours.

Fig. 1.

The bulk of the grain being greatest at this time, the revenue officers may, if they think fit, gauge it. The surface of the barley is now so entirely freed from moisture that it does not feel damp. By degrees, however, it becomes warm, its temperature being 10° Fahr. (5°·5 C.), above that of the atmosphere, and it gives out an agreeably fruity smell. If at this time the hand is thrust into the heap it becomes bedewed with moisture. At this sweating stage the germination commences; the fibrils of the radicle shoot forth from the tip of every grain, and a white elevation appears, which soon separates into three or more rapidly increasing radicles. About a day after this appearance, the plumula (acrospire of the maltster), peeps forth from the same point, and would proceed under the husk until it appeared at the other end of the seed as a green leaflet; but this never happens in malting, as the operation is finished before it takes place.

About ninety-six hours after the barley has been taken out of the steep the heat is the greatest, consequently the radicles increase in length with great rapidity, and their growth must be checked by artificial means. The time at which this should be done constitutes the chief art of the maltster.

The barley must be spread out thinner upon the floor, and turned several times a-day—as shown in Fig. 1—the interior being always brought to the surface by the spades of the workmen. The depth, originally 15 or 16 inches, is slightly lessened

at each turning, till it is at last not more than 3 or 4 inches. Two spadings per day are generally requisite. At this period of spreading or flooring the temperature in England is about 62° Fahr. (16°·6 C.), but in Scotland only 56° or 57° Fahr. (13°·3 and 13°·8 C.)

The rudiments of the stem, or the plumula, sprout forth about a day after the appearance of the radicles.

To a limited extent the barley absorbs oxygen and emits carbonic acid, just as animals do in breathing; the grain loses from 1½ to 3 per cent. of its weight upon the malt floor, a portion of this being due to waste particles. As the acrospire creeps along the surface of the seed the constituents undergo a remarkable alteration. The gluten and mucilage in a great degree disappear, the colour becomes whiter, and the substance so friable that it crumbles into meal between the fingers. This is the great object of malting, which is accomplished when the acrospire has reached the end of the seed. At this period the growth must be completely stopped. The duration of the germination in England may be reckoned fourteen days; but in Scotland eighteen or even twenty-one are required, owing to the lower temperature of the couch.

The shorter the period within these limits the better, as there will be a quicker return of capital, and a superior malt produced. In dry weather it is sometimes necessary to moisten the barley upon the couch.

If an offensive odour, somewhat resembling that of rotten apples, be observed to arise from the couch, it is a bad omen, showing that either the quality of the barley was inferior, or that, through carelessness, the workmen have crushed a number of the grains in turning.

On this account, when the weather causes too quick germination, it is better to arrest it by spreading the heap out thinner than by turning it too often.

Comparing different samples of barley, it will be found that the best grain develops the acrospire quicker than the radicles, and thus gives rise to a greater production of the saccharine principle: this conversion advances and keeps pace with the growth of the acrospire, so that the portion of the grain to which it has not reached remains in its unaltered starchy state. The conversion is never complete till the acrospire has attained the opposite end of the grain to that from which it sprung; hence one portion of the corn may be "sugary," while the other is still tasteless. If the grain was allowed to vegetate still longer, the future stem would become visibly green, it would shoot forth rapidly, the interior of the grain would appear milky, a complete exhaustion of all its useful constituents would ensue, and nothing but husk remain.

In France the brewers, who are generally their own maltsters, seldom leave the barley on the couch longer than eight or ten days, which is too short a period, even when allowance is made for the extra warmth of the climate; hence the wort made from the same quantity of malt is much inferior to that of the English brewer.

At the conclusion of the germination the radicles have become once and a half as long as the barley, and are so contorted that the corns hook one into another, but the acrospire is only just beginning to make its appearance.

A moderate temperature is best fitted for malting; it cannot, therefore, be well carried on in the heat of summer or the cold of winter.

Malt floors should be placed in substantial thick-walled buildings, the more concealed from the rays of the sun the better, so that the temperature of the interior may be uniformly from 59° to 60° Fahr. (15°·0 to 15°·5 C.) They are considered by some maltsters to be better when slightly sunk beneath the surface of the ground, provided that the situation is dry.

During germination portions of the glutinous constituent of the grain disappear, which it is conjectured have passed into the radicles, while a portion of the starch is converted into sugar and mucilage. The change is similar to that which starch undergoes when dissolved in water, and digested at a heat of about 160° Fahr. (71°·1 C.) with a little gluten. The thick paste becomes by degrees liquid, transparent, and sweetish to the taste, the solution containing sugar and gum mixed with some unaltered starch. At the same time the gluten undergoes a change and becomes acid, so that only a certain amount of starch can be thus modified by a quantity of gluten. By the artificial growth upon the malt floor the whole of the gluten and albumen is not decomposed, and only about one-half of the starch is changed into sugar; by a continuance of the germination the remainder would only assist the growth of the roots and stems; it is, however, nearly altogether converted into sugar in the brewer's operation of mashing.

If the grain is suffered to sprout in the couch it will never be even afterwards, as those corns which are sprouted will attract more than their proper share of moisture; moving and turning at proper intervals is intended to retard this and cause each corn to shoot almost simultaneously.

The Flooring.—In this operation the grain is turned inside out from the couch into the bed, which is made to occupy two or three times as much space as the former, according to the temperature. It may lie here for about six hours, observing in the interim whether the grains are commencing to shoot; or, if this is not the case, giving it a gentle turning, and spreading it out thinner, before the expiration of the period named. It may be laid all the width of the floor, and permitted to remain for another six hours, when all the healthy corns will have sprouted; it is then again thinned, and after this, while it is in full vigour, often turned. By this manipulation the root is kept short and bushy, and retains the moisture to the period of its withering, if the process be of sufficient duration, without sprinkling.

The root begins to fade about the eleventh or twelfth day.

If, on taking a handful of the grain from the floor, it smells faint, and the skin is glossy or wet, it requires turning. After this it will smell fresh, and

the grain, instead of being glossy, will be dry. If the turning is omitted at the proper time the root will be of unequal length.

On the grain beginning to wither, it may be spread out thicker, to generate a little more warmth and to mellow it, still keeping it frequently turned, to prevent a glossy appearance, until the moisture is further expelled, and also to retard the progress of the acrospire.

The grain, when ready for drying, must easily rub to meal between the fingers, after being deprived of the skin.

Kiln-drying.—When the malt has become perceptibly dry to the hand upon the floor, it is taken to the kiln and hardened with artificial heat, to prevent all further growth, and enable it to be kept, without fear of change, for use.

The malt should be evenly spread upon the drying cloth or floor, in a layer varying from 3 to 10 inches in thickness, according to the kind of malt (pale, yellow, or brown) which is to be produced, and a heat of from 90° to 100° Fahr. (32°·2 to 37°·7 C.), steadily maintained, till the moisture is nearly all driven off. During this time the malt must be turned over, at first frequently, and towards the conclusion every third or fourth hour. When nearly dry, the temperature of the kiln should stand between 145° and 165° Fahr. (62°·7 to 73°·8 C.), and this heat must be maintained till the grain has acquired the desired colour.

The fire is now allowed to die out, and the malt is left on the kiln till sufficiently cool, this result being greatly accelerated by the stream of cold air rising up through the bars of the grate. Thoroughly dry brown malt may, however, by damping the fire, be taken hot off the plates, and cooled in some contiguous apartment. The kiln-drying should not be hurried; many persons allow the operation to occupy two days.

The temperature of the kiln should, in all cases, be most steadily maintained, and, when required, gradually elevated.

If the drying commences with too great a heat, the outer part of the grain hardens, and prevents the interior moisture from evaporating; should this be driven off by too high a temperature, the husk will, in all probability, split, and the farina become horny and very refractory in the mash.

It is preferable, therefore, to brown malt by a long-continued moderate heat, than to apply a strong one for a shorter period, which might carbonize a portion of the mucilaginous sugar, thereby deteriorating the value of the product.

In this manner the sweet very often changes to a bitter principle.

The malt, when prepared, must be kept in a dry loft, where it can be occasionally turned over till used.

During the drying the roots and acrospire of the barley become brittle, and are, by the friction of turning, &c., broken off, and are afterwards separated by a fine wire sieve—Fig. 2. This operation is termed cleaning.

The *bulk* of good malt exceeds that of the barley from which it was fabricated by about 8 or 9 per cent.

Kiln-dried malt has a peculiar, agreeable, and faintly-burnt taste, probably from some empyreumatic oil generated in the husk, and which imparts its flavour to the beer, and at the same time it assists in preserving it. The skilful preparation of the malt, therefore, necessarily exercises a very great influence on the worts which are prepared from it. If the germination be pushed too far, a portion of the valuable matter is wasted, while, if it is not carried on sufficiently long, the malt will be too raw, and much of its starch will remain insoluble; if it is too highly kiln-dried, a portion of its sugar will become caramelized and bitter; and if the sweating was irregular or imperfect, much of the barley will be lumpy and useless.

The grains of good malt are round and full, break freely between the teeth, have a sweetish taste, an agreeable smell, and are full of soft flour. They give no unpleasant taste on being masticated; are not hard, but will give a free white streak, like chalk,

Fig. 2.

when drawn across the fibres of wood; and lastly, will swim on water, which is not the case with unmalted barley.

Malt-kiln.—The construction of a well-contrived malt-kiln is shown in Figs. 3, 4, 5, and 6, the first being the ground plan; the second, a vertical section; the third, a horizontal, and the fourth, a vertical section in the line of the malt plates. The same letters in each of the figures are indicative of the same parts of the kiln.

In the middle, upon a wall of brickwork 4 feet high, is supported a cast-iron cupola-shaped oven, and beneath it are the grate and ash-pit. The smoke escapes through two equidistant pipes into the chimney. *a* is the grate, 9 inches below the sole of the oven, *b*; *c c c c*, are four strong 9-inch pillars of brickwork bearing the stone lintel, *m*; *d d d d d d*, are similar supports for the girder and joists, upon which are laid perforated plates; *e* indicates a vaulted arch on each of the four sides of the kiln; *f* is a space between the kiln and the side arch, allowing of the inspection and cleaning of the kiln; *g g*, walls, on which the arches rest, on each side of the kiln; *h*, the

ash-pit; k is the furnace-door; and $l\ l$ are junction pieces connecting the pipes, $r\ r$, with the kiln.

These smoke-draughts rest about 3 feet from the walls, and a similar distance from the malt-plates, upon iron supports secured to the arches. They are indicated in the vertical section—Fig. 4—by the letters $u\ u$; at $s\ s$—Fig. 6—they enter the chimney, to which is supplied two register or damper plates, intended to regulate the draught. These registers are represented by $t\ t$; the lintel, m—Fig. 4—is intended to cause the heat to spread laterally, instead of ascending in one mass in the middle, and prevents any combustible particles from falling upon the iron cupola; $n\ n$ are main girders of iron supporting the joists, $o\ o$, of the same material, upon which the perforated plates, p, lie; q is a vapour pipe in the middle of the roof, allowing the steam of the drying malt to escape.

Fig. 3.

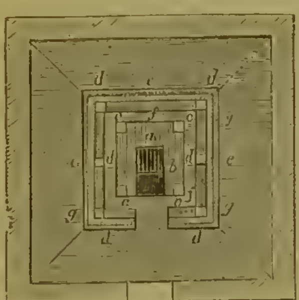


Fig. 4.

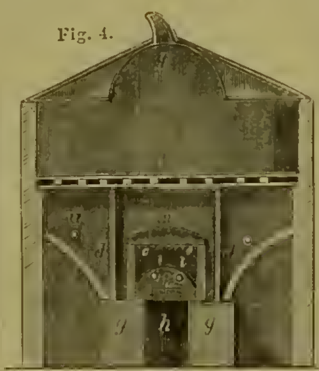
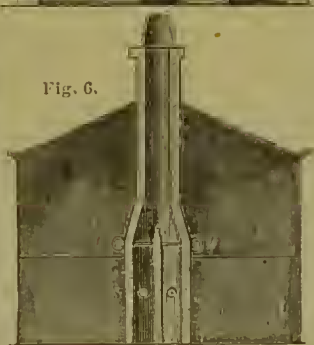


Fig. 5

Fig. 6.



This kiln may be heated either with coal, coke, or wood. The size is about 20 feet square, but it may either be proportionally enlarged or diminished, as seems advisable. The perforated floor should be large enough for the contents of one couch or steep to be spread out upon.

It can be heated by means of steam pipes, laid irregularly, or in parallel lines under it, or a wire-gauze web might be extended upon such pipes. This steam apparatus might, without danger, be supported by joists of timber. For drying the pale malt of the brewers, this plan is well adapted.

Dr. C. Graham states that in Belgium they put a stop to germination, as soon as it has got far enough, by the process of drying simply in air, and so in some cases do the North Germans. Weiss beer is made with air-dried malt. It has to English taste a very raw, uncooked sort of flavour; but not only in Berlin, but also in Magdeburg and elsewhere, people are excessively fond of it. It is made not only from air-dried malt, but sometimes from a mixture of air-dried malt and raw grain. The worst characteristic of it is that it does not keep well, and that it has none of that pleasant empyreumatic flavour which kiln-dried malt has. The beer produced from kiln-dried malt has just the same advantage over air-dried malt which a cooked potato has over a raw one.

As regards the action of heat upon the starchy, saccharine, and albuminous substances contained in the barley, if they be dry, a higher temperature is required to produce as much decomposition as is produced by a low temperature when moisture is present. It therefore follows that, in order to apply the artificial drying which is done in a kiln, the great bulk of moisture which is there, and which still remains there in the English system, ought previously as much as possible to be got rid of. This may be readily done by imitating some of the Continental maltsters who, after the germination has gone on far enough, place their malt on the upper floors, where it is exposed to a current of air passing over it. In that way the rootlet is rapidly withered, the germination stopped, and the grain or malt is rapidly dried. The Germans, after having put it on the floor, place it on an upper kiln at a temperature of about 100° Fahr. (37°·7 C.), and after it has remained there for about five hours, it is let down to a lower kiln at a temperature of about 160° to 167° Fahr. (71°·1 to 75° C.). Now, as before remarked, too sudden a heat produces hardening or what is called vitrifaction of the starchy or dextrine matter; on the other hand, a too low heat leaves the grain with moisture, and still very liable to absorb more, and containing a larger quantity of the destructive albuminous constituents, and less of the empyreumatic bodies.

As regards colour, if the malt is previously dried, a perfectly pale malt is obtained at a temperature of 145° to 150° Fahr. (62°·7 to 65°·5 C.). Of course, if to obtain amber or brown, it must be heated somewhat more. High-coloured malts have some advantage over pale-coloured. In the first place there is more dextrine produced, and in the second place more of the albuminous matters are rendered insoluble; lastly, there is more colour. When this is carried to a very high point, as is done in the manufacture of English porter, this is a matter of great importance, because it not only fulfils the conditions which the consumer requires, but by the advantages which the high colour presents, it, like charity, covers a multitude of sins. It is much more easy to work with a high-dried malt than with a very low-dried malt.

With respect to the thickness on the floor, Dr. Graham considers that in England it is far too great, being 12 and 18 inches thick, and sometimes even thicker still, and very wet. Now, barley kept in a very moist condition at 80°, 90°, and

100° Fahr. (26°·6, 32°·2 and 37°·7 C.), is in the condition necessary for the production of acid. He states that he never yet examined a sample of malt dried in that way which did not contain acid. He says—"Not only do I consider the thickness too great, but I even consider one kiln floor to be bad. In the first place, because the malt must be thicker, and because it is more difficult to regulate the heat than when there are two, and also because it is more difficult to get rid of the moisture; then lastly, because more time is required, and instead of the process being finished in a few hours, it takes some three or four days, sometimes even more. The advantages which two floors present are very evident. The malt may be thinner, the temperature may be regulated in two distinct stages by having a lower temperature in the higher floor, and a higher temperature in the lower one."

Malt Testing.—The examination of malt may be divided into two main classes; first of all, the physical examination; and secondly, the chemical.

Dr. GRAHAM says:—It is a good plan to take 100 distinct seeds, and examine how far the plumule has grown, and if there is more than 5 per cent. which have projected, it is an indication that there has been a waste of material. If, on the other hand, more than 5 per cent. have been inefficiently germinated, that is also rather an approach to mixing raw grain with malt. There should be no vitrified appearance when broken, because the vitrified appearance is either due to too sudden heating, or to the barley having been grown upon too rich a soil, being too rich in albumen, or to mixed seed having been employed which did not germinate equally. If 100 seeds are taken (this is an old German rule which has been long known in England also), thrown into water, and just stirred about; if the malt be good, not more than five should sink. If more than 5 per cent. sink, then the malt is not good.

To effect the chemical examination of malt, take 50 grms. of malt, powder them, and place them in a beaker, and add to the powdered malt 300 cubic centimètres (that is 300 grammes) of cold water, and then gradually heat that up through a period of half-an-hour to 140° to 145° Fahr. (60° to 62°·7 C.). After it has reached that temperature the malt should be kept so for one hour, and then should be heated somewhat rapidly, so that at the end of the next half-hour, making two hours altogether, it may have come to the boiling point. Finally, it should boil for five minutes. After that filter and wash it with boiling water. This should be done until such time as the half-litre, which is 500 cubic centimètres, is filled up to the mark indicated on every half-litre flask.

With this solution the different chemical tests can be proceeded with, bearing in mind that this solution contains an extract of 50 grms. in 500 grms. of water, therefore 10 per cent.

The insoluble matter should then be placed in an air bath, with a lamp underneath, where it should be heated for two and a half or three hours to a temperature of 230° Fahr. (110° C.), and weighed. This will give the percentage of "draff," *i.e.*, the amount of insoluble matter.

The process for the determination of the glucose, or grape sugar, and dextrine, is as follows:—From the solution, containing 50 grms. of extract to 500 grms. of water, 50 cubic centimètres are taken and put into a 500 cubic centimètre flask, then 450 cubic centimètres of water are added, making altogether 500 cubic centimètres of liquid, containing 50 cubic centimètres of concentrated solution. FEHLING's solution is next made by dissolving 34·64 grms. of sulphate of copper in 200 cubic centimètres of water. Then add to that 173 grms. of pure Rochelle salt (double tartrate of sodium and potassium), dissolve and add 480 cubic centimètres of caustic soda solution, at a specific gravity of 1·11; and lastly, make the whole up to one litre with water. When using this solution take 10 c.c., dilute with 40 c.c. of water, and boil for some minutes. If a precipitate forms the copper solution is unfit for use.

Ten cubic centimètres of FEHLING's copper solution are equal to ·05 grm. of grape sugar; that is to say, the ·05 grm. of grape sugar reduces the oxide of copper in 10 cubic centimètres of the solution down to the state of suboxide, a precipitate is produced, and the blue colour of the liquid is destroyed.

The dextrine is determined by taking 25 cubic centimètres of the concentrated solution of malt, diluting it down to 200, and adding 4 cubic centimètres of oil of vitriol, and then boiling the whole for two hours to convert the dextrine into glucose; it is then made up to 250 cubic centimètres, and when treated as above with FEHLING's solution, gives the total amount of glucose and dextrine.

Practical brewers take the specific gravity when the wort is cooled down to a proper temperature, and look at the already calculated tables; but, unfortunately, that method gives very inaccurate results, because the density is due to many things besides dextrine and sugar. A much more accurate way is to make the solution, as above mentioned, of 50 grms. of malt made up to 500 with water, then to take a known quantity, 25 cubic centimètres, which will contain 2½ grms., evaporate to dryness, then dry it at 220° to 230° Fahr. (104°·4 to 110° C.) for one hour. This will give the total solid extract. Weigh the residue, and deduct the weight of the vessel, the remainder, multiplied by forty, will give the percentage of solid extract.

A simple way of determining the grape sugar and dextrine is to take 25 cubic centimètres of the extract, and add to it about 150 cubic centimètres of strong spirits of wine; this precipitates the whole of the dextrine, and most of the albumen. It will not filter in this condition, the precipitate being so fine, but after shaking it with animal charcoal for a few minutes it will filter perfectly well; then transfer it into a glass or platinum vessel and evaporate off the alcohol. The more economical method would be to distil it off in a flask, and then afterwards wash out the contents of the flask much in the same way as in determining the original gravity of beer. If what is left in the platinum vessel is evaporated to

dryness, and heated for one or two hours to about 220° to 230 Fahr. (104°·4 to 110° C.), the weight or percentage of grape sugar in the extract is obtained. Now, deducting the percentage of grape sugar thus obtained from the total, gives the amount of dextrine. There must, however, be this correction made, that the total extract is not altogether grape sugar and dextrine. Dr. GRAHAM has found by repeated experiment that there is, roughly speaking, about 2 per cent. of albuminous matters and salts, so that it is necessary to deduct an additional 2 per cent. to obtain the percentage of dextrine. Of course this process is not so accurate as the more scientific but complicated one.

The acidity of the malt solution may be determined by a standard solution of soda or ammonia. The acidity of a cold infusion of the malt should be likewise ascertained. THOMAS POOLEY, who has had very great experience in testing malts, states that if there be much difference between the amount in the cold infusion and in the hot, the malt is likely in the after processes to keep on producing more and more lactic acid. As to the maximum amount which ought to be permitted, about 0·2 to 0·3 per cent. only should be allowed.

The amount of water in malt is determined by crushing some of the malt, say 5 or 10 grains, and drying it at 230° Fahr. (110° C.).

MALTING IN MUNICH.—The barley is steeped till the acrospire seems to be quickened, a circumstance indicated by a swelling at the end of the grain which was attached to the footstalk, as also when, on pressing a pile between two fingers against the thumb nail, a slight projection of the embryo is perceptible. As long, however, as the seed-germ sticks too firm to the husk, it has not been steeped enough for exposure on the underground malt-floor. Nor can deficient steeping be safely made up for afterwards by sprinkling the malt-couch with a watering-can, which is apt to render the malting irregular. The steep-water should be changed repeatedly, according to the degree of foulness and hardness of the barley: first, six hours after immersion, having previously stirred the whole mass several times; afterwards, in winter, every twenty-four, but in summer every twelve hours. It loses none of its substance in this way, whatever vulgar prejudice may think to the contrary. After letting off the last water from the stone cistern, the Bavarians leave the barley to drain in it during four or six hours. It is now taken out and laid on the couch floor in a square heap, 8 or 10 inches high, and it is dexterously turned over, morning and evening, so as to throw the middle portion upon the top and bottom of the new-made couch. When the acrospire has become as long as the grain itself, the malt is carried to the "withering" or drying floor, in the open air, where it is exposed in dry weather during eight to fourteen days, being daily turned over three times with a winnowing shovel. It is next dried on a well-constructed cylinder, or flue-heated malt-kiln, at a gentle clear heat, without allowing it to brown in the slightest degree, while it becomes friable and turns into a fine white meal. Smoked malt is entirely rejected by the best Bavarian brewers. Their malt is dried on a series of wove-wire horizontal shelves, placed over each other; up through the interstices or perforations of which streams of air, heated only to 122° Fahr. (50° C.), rise from the surfaces of rows of hot sheet-iron pipe flues, arranged a little way below the shelves. Into these pipes the smoke and burned air of a little furnace on the ground are admitted. The whole is inclosed in a vaulted chamber, from the top of which a large wooden pipe issues, for conveying away the steam from the drying malt. Each charge may be completely desiccated on this kiln in from eighteen to twenty-four hours by a gentle uniform heat, which does not injure the diastase or discolour the farina.

COMPOSITION OF RAW AND MALTED BARLEY.—PROUST affirms that barley contains a peculiar proximate principle, which, from the Latin name of the grain, he denominated *hordein*. He describes it as a yellow, granular, woody powder, in appearance very much resembling sawdust, and says that it disappears in great quantity during malting, being resolved chiefly into starch and sugar. It has since been found to be a mixture of starch, cellular tissue, and a nitrogenous body.

PROUST states that barley meal contains—

Hordein,	55·0
Starch,	32·0
Sugar,	5·0
	92·0

Dr. T. THOMSON gives no hordein, but—

Starch,	88·0
Sugar,	4·0
	92·0

The analyses of PROUST and THOMSON agree exactly, only one takes the 88·0 to be solely starch, while the other assumes it to be a peculiar principle and that body.

The sugar found in the barley was, no doubt, the result of the action of some of the reagents employed by the above chemists on the starch.

THOMSON looked upon the hordein as merely starch in a peculiar state, somewhat similar to the fibrous matter of potatoes, malting having the effect of converting it into starch and sugar.

This peculiar substance, hordein, is now considered to be formed by kneading barley-meal in water; its presence in so great a quantity as 50 per cent., its being woody and insoluble in both cold and boiling water, its disappearance during the malting, and the increase of gum, sugar, and starch in consequence, are properties incompatible with its being any component part of the grain.

Hordein seems to be an allotropic modification of starch. It is very probable that this state is owing to some impurity or extraneous matter, and that, could this be removed, it would be found to consist of starch only.

Annexed is the mean of ten analyses of barley performed by HERMBSTADT:—

	Centesimally represented.
Water,	10·48
Husk,	11·56
Gluten,	4·92
Albumen,	0·35
Starch,	60·50
Sugar,	4·66
Gum,	4·51
Oil,	0·35
Soluble phosphates, &c.,	0·36
Loss,	2·31
	100·00

The following analyses are by OUDEMANS:—

COMPOSITION OF BARLEY (DRIED).

Starch,	65·7
Dextrine,	5·5
Gluten, insoluble in water, soluble in alcohol,	0·3
Soluble albuminous bodies (coagulable by heat),	0·3
" " (not coagulable),	1·9
Albuminous bodies (insoluble in water or in alcohol),	9·3
Fatty substances,	2·5
Cellulose,	9·4
Ash,	3·1
Water,	0·0
Loss, &c.,	2·0
	100·0

COMPOSITION OF BARLEY AND MALT.

	BARLEY.	MALT.		
	Air dried	Air dried.	Kiln-dried (pale).	Kiln-dried (amber).
Produce of torrefaction,	0·0	0·0	7·8	14·0
Dextrine,	5·6	8·0	6·6	10·2
Starch,	67·0	58·1	58·6	47·6
Sugar,	0·0	0·5	0·7	0·9
Cellulose,	9·6	14·4	10·8	11·5
Albuminous substances,	12·1	13·6	10·1	10·5
Fatty ditto.,	2·6	2·2	2·4	2·6
Ash, &c.,	3·1	3·2	2·7	2·7
	100·0	100·0	100·0	100·0

ALBUMINOUS COMPOUNDS IN BARLEY AND MALT.

	Barley.	Malt.
Gluten, soluble in alcohol,	0·28	0·24
Albuminous substances, coagulable by heat,	0·28	0·45
Do., not coagulable,	1·55	2·08
Insoluble albumen,	7·59	6·23
	9·70	9·10

CONSTITUENTS OF BARLEY.

	FEHLING AND FAISST.		POLSON.	POGGIALE.
	Five Samples Wurtemburg.	Two Samples Wurtemburg, without husk.	New Scotch.	Mean of Analysis.
Water,	13·91 — 15·60	12·97 — 14·33	12	13·7
Starch,	} 79·53 — 81·08	} 78·60 — 82·92	52.7	74·5
Fat,			2·6	0·2
Cellulose,	2·58 — 4·55	1·26 — 1·84	11·5	3·4
Sugar,	——	——	4·2	—
Nitrogenous bodies,	12·01 — 15·73	13·71 — 17·46	13·2	7·8
Nitrogen,	——	——	—	—
Ash,	2·62 — 3·04	2·10 — 2·11	2·8	0·3
Phosphoric acid (P_2O_5),	0·95 — 1·13	0·99 — 1·09	—	—
Silica (SiO_2),	1·51 — 0·86	0·13 — 0·17	—	—

The amount of inorganic matter in different specimens of barley varies very considerably. This might be anticipated from the fact, now generally admitted, that the nitrogenized or nutritive principles of grain or seeds bear a relation to the phosphoric acid present; thus, if the quantity of the latter be small, it follows that the amount of nitrogen is proportionally deficient, and the nutritive effect of the grain will be comparatively low in the scale. The solubility of the albuminous matters, and therefore their capability of being carried into plants, appears to depend on the presence of the phosphates.

Thomson gives the following as the composition of the ash of barley and malt:—

	Centesimally represented. R. D. Thomson. Barley.	Malt.
Potash,	16·00	14·54
Soda,	8·86	6·08
Lime,	3·23	3·89
Magnesia,	4·30	9·82
Ferric oxide,	0·83	1·59
Phosphoric acid (P_2O_5),	36·80	35·34
Sulphuric acid (SO_3),	0·16	—
Chlorine,	0·15	trace.
Silica,	29·67	28·74
	100·00	100·00

COMPOSITION OF THE ASH OF BARLEY (WAY AND OGSTON.)

	Chevalier Barley.					Moldavian.			Long-eared Nottingham or Sandy Soil.
		Clay Soil.	Sandy Soil.	Loamy Soil.	Chalky Soil.		Clay Soil.	Sandy Soil.	
Potash (K_2O),	26·83	22·43	24·97	28·60	37·22	19·78	26·61	22·46	32·02
Soda (Na_2O),	—	1·42	0·51	—	—	0·89	1·26	4·93	1·21
Lime (Ca_2O),	3·62	1·96	2·97	2·97	2·92	4·20	1·26	1·88	3·39
Magnesia (Mg_2O),	4·78	10·00	8·00	6·90	7·63	8·15	9·32	8·17	10·99
Ferric oxide (Fe_4O_3),	1·54	0·87	0·84	1·46	trace.	0·93	0·21	0·10	0·15
Sulphuric acid (SO_3),	1·30	2·82	0·92	trace.	0·26	0·39	0·17	0·53	trace.
Silica (SiO_2),	29·79	22·25	22·08	18·47	17·27	27·66	30·35	28·09	21·12
Carbonic acid (CO_2),	4·35	—	—	—	—	—	—	—	0·48
Phosphoric acid (P_2O_5),	25·32	37·67	38·26	38·78	30·76	37·99	30·08	32·92	29·92
Potassium chloride,	—	—	—	1·29	1·93	—	—	—	—
Sodium chloride,	2·47	0·56	1 44	1·59	2·01	trace.	0·41	0·61	0·72
	100·00	99·98	99·99	100·00	100·00	99·99	100·00	99·99	100·00
Ash in 100 parts of fresh barley,	2·32	2·65	2·47	2·28	2·39	2·28	2·55	2·07	2·20
Ash in 100 parts of dry barley,	2·03	2·30	2·15	2·07	2·13	2·03	2·31	1·79	1·99
Sulphur in 1000 parts of dry barley,	3·53	0·96	1·21	0·74	1·83	2·42	1·54	1·58	1·41

The ultimate constituents of a sample of barley, and of malt made from it, is given below, thus showing the alteration in the grain by malting :—

	Barley.		Malt.	
	Natural State.	At 212°.	Natural State.	At 212°.
Carbon, ...	41·64	46·11	42·44	43·93
Hydrogen, ..	6·02	6·65	6·64	7·00
Nitrogen,...	1·81	2·01	1·11	1·29
Oxygen,.....	37·66	41·06	43·08	46·51
Ash,.......	3·41	4·17	1·68	1·27
Water,.....	9·46	—	5·05	—
	100·00	100·00	100·00	100·00

The mean of a number of experiments relative to the loss which barley sustains by malting, indicated 19 per cent.

The whole of the loss is not solid matter, as barley uncrushed contains 13·1 per cent. of water; and malt, in the same condition, 7·06 per cent.

There thus remain 13 per cent. of solid loss.

MUSPRATT found that a mean of several trials gave for the ash of barley 3·0; and for that of malt, 2·52 per cent. Now, as 100 of the former are equal to 80 of the latter, the quantity of ash which malt should contain is 2·42, if the loss of organic and inorganic matter was equable, which it is observed to be, almost approximately, from this experiment; for the relation of the ash which has disappeared, or 0·48 per cent., bears almost the some proportion to the organic matter removed, as the total quantity of ash in barley does to the whole of the organic matter in that grain. Thus, barley contains 84 per cent of *dry* organic matter and 3 per cent. of ash, while malt has lost 0·48 per cent. of ash, and 12·52 of organic matter, and by calculation—

As 3 : 0·48 :: 84 : 13·4.

A remarkable coincidence, as if proving that water is incapable of removing the inorganic portion of plants, until the organic matter has undergone such a change as to allow the ash to separate.

From the above, the loss sustained by barley in malting may be stated thus :—

Water,................................	6·00
Saline matter,........................	0·48
Organic matter,.......................	12·52
	19·00

WATER.—Good water in a brewery is of the utmost importance, but what should constitute the composition of a good water is with brewers a much debated question.

Perhaps nothing in nature is more variable in character than this apparently simple fluid, which is not the *aqua pura* which it seems, and which it was formerly believed to be, but a heterogeneous mixture of alkaline and metallic salts, acids, gases, and occasionally even animal and vegetable matter, some of which are held in chemical union, and others in mechanical suspension. Pure water, or hydrogen oxide (H_2O), is only obtained by art.

Some brewers prefer soft and others hard water, whilst a few are quite indifferent on this point.

Were the density of the worts, and the value of cold water for refrigeration and other purposes, alone to be considered, there would be little hesitation in their choice; but the constituents of the water are of importance, accordingly as the beer to be brewed is to be drunk speedily, or is intended to be kept for a prolonged period; therefore, though a brewer already established can seldom choose a different spring or stream, the case is much altered when the site of a new brewhouse is to be selected.

Water entirely free from saline matter, or which holds it only in very small quantity, is unfit for brewing.

In England nearly every one at all acquainted with brewing holds that water which contains a large quantity of gypsum (sulphate of lime), earthy carbonates, and no organic matter, is best adapted for this purpose.

Many reasons are given for this. HASSALL says : —During ebullition the excess of carbonic acid in the water, by which the carbonates of lime and magnesia are retained in solution, is expelled, and those salts are precipitated. Again, the alkaline phosphates present in malt have the power of converting sulphate of lime into phosphate, which is thrown down ; an alkaline sulphate, which is soluble, being synchronously formed. The greater part of the phosphate of lime produced is redissolved in the acid generated during the fermentation; consequently the water, from being hard, thus becomes comparatively soft, and in this state is well suited for extracting the active properties of the malt and hops.

This is entirely speculative, and is not based on experiment; nevertheless, the theory is ingenious.

Another advantage claimed for the use of hard water is, that more saccharine matter can be left in the beer, by which its fulness and flavour will be increased, and its liability to become acid prevented.

German brewers, however, consider the presence of mineral salts in the water as uniformly bad, and MÜLDER has pointed out that the action of these salts in producing hard water in the mashing process, is very much the same as that which occurs when peas or beans are boiled in hard water, as compared with the result when they are boiled in soft water. In the case of vegetables, hard water produces a leathery insoluble toughness in the skin, and prevents it bursting; whereas the soft water allows the contents to come out more easily. MÜLDER therefore says :—"I object to keeping the albuminous matter insoluble ; I want to get all that is possible out of the malt."

English brewers, on the other hand, working on a different system, and brewing beers which are not intended to be drunk for some months afterwards, are justly afraid of having too large a quantity of albuminous matter in the solution from the mash, because these albuminous constituents are the most powerful agents in continuing fermentation beyond the point at which they wish it to cease.

Water loaded with organic matter, like that of the Thames, is a decided loss to the brewer, as the vegetable and animal remains are decomposed during brewing, and carry with them some portion of the

strength of the wort, besides rendering it and the beer liable to spoil.

Messrs. Allsopp & Sons, Messrs. Bass & Co., Messrs. Salt & Co., and other eminent Burton brewers, have long been celebrated for the quality of their beer, and many conjectures have been made to account for the excellence and superiority of the article brewed in that locality. Their success has arisen in a great measure from the quality of the water they use. The water from the Burton springs is very hard, and is remarkable for its quantity of earthy and alkaline sulphates and carbonates, and, *à priori*, it would be considered but ill adapted for the purposes of the brewer. This, however, as long experience has shown, is not the case.

The following is an analysis by Dr. Böttinger, brewer to Messrs. Allsopp & Sons, of the water used in that celebrated establishment:—

	Amount of Ingredients in the Imper. gallon. Represented in Grains.
Chloride of sodium,	10·12
Sulphate of potash,	7·65
Sulphate of lime,	18·96
Sulphate of magnesia,	9·95
Carbonate of lime,	15·51
Carbonate of magnesia,	1·70
Carbonate of iron,	0·60
Silica,	0·79
	65·28

Some years ago Cooper analyzed water taken from a well at the brewery of Messrs. Bass & Co. He found—

Carbonate of lime,	9·93
Sulphate of lime,	54·40
Chloride of calcium,	13·28
Sulphate of magnesia,	0·83
	78·44

The whole of the water used at Burton for brewing is spring water, and not that of the river Trent, as has been erroneously supposed.

On boiling it deposits a large amount of carbonates of calcium and magnesium, besides a small quantity of calcium sulphate; a little iron, which it contains, becomes also eliminated.

The geological formation from which this water appears to emanate is New Red Sandstone; in the immediate vicinity of Burton there are large strata of new red marl, with a considerable amount of gypsum.

The water employed at the brewery of Messrs. Tetley & Son, Leeds, bears some analogy to the preceding, as will be seen on referring to the annexed analysis by Muspratt.

	Per Gallon.	
Carbonate of lime, Carbonate of magnesia,	19·78	grains.
Carbonate of the protoxide of iron (Ferrous carbonate)	0·93	"
Sulphate of lime,	4·97	"
Sulphate of soda,	13·09	"
Sulphate of magnesia,	9·73	"
Chloride of sodium,	7·11	"
Chloride of magnesium,	4·71	"
Loss,	1·72	"
	62·07	

The three waters contain a varying amount of carbonic acid in the uncombined state, keeping the carbonates in solution.

Muspratt suggests that when brewers in certain districts are compelled to use soft water, or that which runs off moors or fens, for want of better, they should impregnate them at second hand with gypsum, or with such limestones as are easily procurable. He states that this plan has been found most serviceable, and the ale obtained from such artificial water has nearly equalled the renowned product of Burton.

The imitation of the Burton water can be rendered more complete by adding salt as well as gypsum to any soft water.

Dr. Graham thinks that though the sulphate of lime has certainly very much to do with the properties of the Burton water; nevertheless something is also due to the chlorides of sodium, magnesium, calcium, &c., likewise present. Practical brewers are aware that in many cases when the water contains a certain quantity of chlorides, the ale produced is as much to be depended on for its long keeping qualities as that made with water containing sulphate of lime.

Hops.—The wort, as prepared from malt alone, is unpalatable. To make it potable, and insure the permanence of its flavour, it has been found necessary to make some addition to it previous to fermentation. This effect is best produced by means of hops.

Hops are the strobiles or catkins of *humulus lupulus*, a diœcious plant belonging to the natural order Urticaceæ, the culture of which was first introduced into England from Flanders in the reign of Henry VIII.

The various parts of the hop are scales, nuts, and lupulinic grains or glands. The scales are the enlarged and persistent bracts enclosing the nuts, which are small, hard, nearly globular, and covered with aromatic superficial glands, commonly termed "yellow powder" or "lupulin." These form the most important part of the strobiles.

Dry hops ought to yield about one-sixth of these grains. They are usually mingled with silica.

Pereira says they are rounded, of a cellular texture, golden-yellow coloured, somewhat transparent, and are sessile, or nearly so.

The common centre around which the cells are arranged has been denominated the *hilum*. They lose their spherical form by drying, and, when placed in water, give out an immense number of minute globules. Under different circumstances they become ruptured, allowing an inner envelope to escape.

The scales and lupulinic grains have been analyzed by Payen, Chevallier, and Pelletan, with the following results:—

Lupulinic Grains.

	Centesimally represented.
Volatile oil,	2·00
Bitter principle—lupulin,	10·30
Resin,	55·00
Lignin,	32·00
Fatty, astringent, and gummy matters, malic and carbonic acids, salts, as malate of lime, acetate of ammonia, chloride of potassium, sulphate of potassa, &c.,	traces.
Loss,	·70
	100·00

The scales were found to consist of astringent matter, inert colouring matter, chlorophyl, gum, lignin, and salts of potassium, calcium, and ammonium, containing acetic, hydrochloric, sulphuric, nitric, and other acids.

The scales usually have lupulinic matter adhering, from which it is almost impossible to free them.

Dr. Yves also examined lupulin, and obtained—

	Centesimally represented.
Tannin,	4·16
Extractive,	8·33
Bitter principle,	9·16
Wax,	10·00
Resin,	30·00
Lignin,	38·33
Loss,	·02
	100·00

Oil of Hops.—A volatile oil is procured by distilling the lupulinic grains or the hops with water. It has a yellowish colour, an acrid taste, and its odour is similar to that of the strobiles. It is partially soluble in water, but more so in alcohol and ether. It has a specific gravity of 0·910, becomes resinified by keeping, and is said to have a narcotic influence on the system. The water which distils over with the oil contains acetate of ammonia.

Rudolph Wagner investigated oil of hops. He distilled the oil from fresh hops with water. It constituted about 8 per cent. of the air-dried flowers. It possessed a clear brownish-yellow colour, and had a strong odour of hops, and a slightly bitter taste analogous to thyme. Its specific gravity was 0·908 at 61° Fahr. (16°·1 C.). It scarcely reddened litmus paper, and was very sparingly soluble in water, requiring more than 600 times its weight for solution. It contained no sulphur. The oil, rendered anhydrous by distillation over fused chloride of calcium, partly evaporates at a temperature below the boiling point of water. It begins to boil at 257° Fahr. (125° C.), rising to 347° Fahr. (175° C.), where it remains stationary for some time, and at which temperature nearly one-sixth of the clear oil distils over. The portion passing over between 347° Fahr. and 437° Fahr. (175° C. and 225° C.), and constituting one-half of the oil, was also very clear, and had the odour of the crude oil. That which passed over between 437° Fahr. and 455° Fahr. (225° C. to 235° C.) was of a yellow colour. The residue in the retort, about one-sixth of the quantity submitted to distillation, was brownish, and like turpentine. It is therefore evident that oil of hops is a mixture of oils. The crude oil does not give, with ammoniacal silver solution, a metallic mirror. It is therefore not an aldehyde. When mixed with alcohol-potassa, it becomes brown, and when distilled affords alcohol and an oil having the odour of rosemary.

After the greatest part of the oil and spirit has distilled over a violent action takes place, hydrogen is evolved, and potassium carbonate, mixed with a potassium salt of a volatile fatty acid, remains: the latter, when decomposed with diluted sulphuric acid, evolves an odour indicating the presence of caprylic and pelargonic acids.

From Payen and Chevallier's analyses and report the oil was supposed to resemble oils of mustard, asafœtida, &c., and to belong to the ethereal oils containing sulphur; that it dissolved largely in water, and on this account preserved the beer; and that it acted partly as the narcotic in beer and hops.

According to Wagner the oil is isomeric with Borneo camphor, oils of cajeput and bergamot, and with the aldehyde of camphoric acid. This chemist, in conjunction with Dr. Bibra, made experiments upon animals to ascertain whether the oil of hops acted as a narcotic. They found it had no such action.

Lupulin.—This substance is the yellow, granular, aromatic powder which is found at the base of the cones of the hops, and forms from 8 to 18 per cent. of the cones themselves.

Lupulin contains five different substances, viz., a volatile oil, a resin, a nitrogenous substance, a bitter principle, and a gummy substance. The cones contain about 2 per cent. of the volatile oil of hops. The oil and resin combined probably gives to beer its agreeable aromatic odour, whilst the bitter principle (lupulin) tends to preserve it.

The bitter principle of hops, lupulite or true lupulin, may be obtained by treating the aqueous extract of lupulinic grains, combined with a little lime, with alcohol. The solution thus formed is to be evaporated, the mass treated with water, and the solution again boiled to dryness. The residue, on washing with ether, is lupulin. It is uncrystallizable, white, very bitter, soluble in twenty parts of water, very soluble in alcohol, and in ether slightly so. The aqueous solution froths on agitation, and according to Pereira, gives no precipitate with tincture of galls or acetate of lead. Lupulin contains no nitrogen. It is said to have caused loss of appetite and diminished digestive power when administered in small doses.

Dr. Yves first applied the term lupulin to the pollen or, as it is technically denominated, the "condition" of the hop; the name has been applied since, however, to the bitter extract of the scales.

Other Constituents.—The tannin serves, in brewing, to precipitate the nitrogenized or albuminous matter of the barley, and therefore assists clarification.

The resin has a golden-yellow colour, becomes orange-yellow on exposure to the air, dissolves both in alcohol and ether, and is apparently the oil changed by oxidation.

A decoction of hops feebly reddens litmus, owing to free acid being present; sulphuric and tannic acids, and also lime, may be detected in it even by those who have little experience in analysis.

Hops, in their usual marketable state, lose between 11 and 12 per cent. of their weight when dried at 212° Fahr. (100° C.), and leave, on burning, from 5 to 8 per cent of ash.

Holden obtained, on incinerating a good sample of hops, 7·708 per cent. of inorganic residue.

The ash of hops varies very much in its composition, as may be seen from inspection of the analyses given below:—

Constituents of the Ash of Hop Cones.

	Way & Ogston.			H. Watts.
	Bentley Variety.	Golding Variety.	Grape Variety.	Grape Variety.
Potash, ...	11·98	24·88	25·56	19·41
Soda, ...	—	—	—	0·70
Lime, ...	17·93	21·59	18·47	14·15
Magnesia, ...	5·94	4·69	5·27	5·34
Alumina, ...	—	—	—	1·18
Ferric Oxide, ...	1·86	1·75	1·41	2·71
Sulphuric Acid, ...	7·01	7·27	11·68	8·28
Chlorine, ...	—	—	—	2·26
Silica, ...	22·97	19·71	9·99	17·88
Carbonic Acid, ...	5·44	2·17	4·54	11·01
Phosphoric Acid, ...	21·38	14·47	17·58	14·64
Chloride of Potassium, ...	5·15	—	4·34	—
Chloride of Sodium, ...	—	3·42	0·12	—
Charcoal and Loss, ...	—	—	—	2·44
	99·96	99·95	98·96	100·00
Ash per cent. of dry hops, ...	8·07	5·95	7·21	—
" " fresh hops, ...	7 27	5·22	6·52	6·5

Preparation.—The drying of the hop constitutes a very important part of its management; it is performed in kilns, generally of very unscientific construction, and apparently capable of great improvement.

In Sussex these are termed "oast-houses." The heat imparted by the fire in drying is of great importance, and should in no instance exceed 119° or 120° Fahr. (48°·3 to 48°·8 C.).

The farina or pollen which falls through the hair-cloth or wire, in the course of desiccation, is a valuable article, and is denominated "hop-dust." If care is taken that no particles of fire fall into the kiln-pit, and the hop-dust be frequently removed therefrom, so as to insure its freedom from extraneous matter, it is scarcely less useful to the brewer than hops themselves. One pound of the dust is equal to four times the quantity of the strobiles. In dark-coloured or common beer a small amount may always be used without injury.

According to Brande, in order to give the hops a good colour, they are subjected to fumigation with sulphurous acid; after this process they are packed into sacks or "pockets," and subjected to great pressure, so as to prevent access of air and their consequent deterioration.

Qualities.—The medicinal properties of hops are numerous. The odorous emanations arising from them possess, according to Pereira, marked narcotic properties. Hence a pillow of the cones has often been prescribed to promote sleep, in cases where the administration could not be effected, or would have been objectionable. Probably the imagination has much to do with the effect produced. Both infusion and tincture of hops are mild and agreeable aromatic tonics. They sometimes manifest diuretic, or, when the skin is kept warm, sudorific qualities. Their sedative, soporific, and anodyne properties are very uncertain.

The lupulinic grains are aromatic and tonic, and appear to be soothing, tranquillizing, and slightly sedative and soporific. Hops have been given internally to relieve restlessness consequent upon exhaustion or fatigue, to induce sleep in the wakefulness of mania and other maladies, to calm nervous irritation, and to relieve pain in gout and rheumatism. They have also been applied topically in the form of a fomentation or poultice, as a resolvent or discutient in painful swellings or tumours.

The properties of hops in brewing are important, but may be given in few words.

They render the beer more stimulant and cordial, and the bitter principle overcomes the disagreeable sweetness arising from the malt, and which, if unneutralized, might be offensive, if not injurious, to persons having weak digestive organs.

The stimulating and strengthening qualities found in bitter beer, may be said to be owing almost entirely to the hops.

They are slightly anti-fermentive, and but for the use of them in brewing the ale produced would soon undergo the acetous fermentation, or, in popular language, become sour.

Selection.—The flavour of the Golding or Farnham hops is rich and delicate, but the plant is one of the most tender cultivated, and the crop is uncertain. They are the heaviest, consequently possessing the greatest amount of farina or condition, and the flower is the most diminutive.

The Flemish plant produces a large flower, often 3 inches in length, and is considered as one of the most hardy kinds. It is productive, but of light weight, and is ill-flavoured.

In the districts of Kent and Sussex the Canterbury grape, a very good and useful hop in the trade, is much cultivated.

Other varieties are produced in various parts of the country, especially in a district called North Clay, in Nottinghamshire. These hops are strong, and fit only for porter brewing, even when mellowed by age.

Farnhams are in much repute with brewers, and bring a high price. The North Clays rank next in taste, and fetch a better price with a certain class of buyers than those from Kent, though not generally so high as the Farnham variety. Those grown in the neighbourhood of Canterbury are much prized. The produce of the county of Kent is pre-eminent both for strength and flavour, but varies considerably as the season is more or less propitious. The Wealds are celebrated in some of the southern and midland counties, but in those more north, as in Cheshire and Lancashire, the Worcesters are preferred for their mildness, and for the grateful sensation they yield; some use a few Sussex or Kents with them, but most brewers in the counties just referred to reject the growth of Kent as unpleasing to their customers.

But however good the produce of any district may be in general, it must not be supposed that there are no bad samples of those varieties.

Such lots should be chosen as are heaviest, because it is the farina which gives weight; and hops which lose a part of it from fine weather or over-ripeness, in picking or turning on the "oast," will considerably diminish in gravity.

They should feel clammy when handled, should

be uniform in colour, without greenish particles in the flower, and full of hard seeds and farina or "condition." The brighter the colour the greater the estimation in which the sample is held.

Mould may be discovered in the sample by the sprig of the flower being partly bare of leaf. Particular attention must also be paid to crust proceeding from damp or bad keeping, as it injures the quality more than age.

From the uncertainty of the seasons, the hop is an article liable to considerable fluctuations in its commercial value. The duty upon hops was formerly 2*d.* per lb., with 5 per cent. added. In 1861 this was reduced to $1\frac{1}{2}$*d.* In 1863 the duty was wholly repealed. Latterly foreign hops have been used to a considerable extent by many brewers, even in the manufacture of the finest ales; they do not, however, possess that richness of flavour so characteristic of the English growth, and hence they are never used alone, but mixed with English hops in different proportions, varying from a third to a sixth of the latter. This mixture is found to answer tolerably well, where considerable bitterness is required and the flavour is thought to be unimportant.

A "pocket" of hops, if they be good in quality, well cured, and tightly pressed, will weigh about $1\frac{1}{2}$ cwt. This is the finest sort for ale-brewing.

The brown varieties used for porter and stout are packed in coarse bags, which should weigh about $2\frac{1}{4}$ cwts.

If the weight of either sort exceeds or falls much short of this medium there is reason to suspect that the hops are of inferior quality, or have been badly dressed for market.

Brewing.—This operation may be divided into six sections, viz.: 1, Pumping; 2, grinding; 3, mashing; 4, boiling; 5, cooling; 6, fermenting and cleansing.

Pumping.—The water or "liquor" has nearly always to be pumped, and in some cases also the wort or beer. As the pumping of wort or beer will be referred to in other sections, pumping the water, or as it is termed in the brewery "liquor," need only be noted in this.

A good supply of this most important "liquor" is always necessary, and is generally best obtained from a well. A high service of water is in some towns supplied by water works, and occasionally used for brewing. This of course saves pumping, but liquor from a well is generally considered best for brewing purposes. It is also generally colder, and therefore better adapted for refrigerating and attemperating. It is essential that the pumps be large enough to do their work in a short time, so that in breweries of a large size the machinery need not be worked on purpose for pumping only. The liquor is stored in a vessel called a "cold liquor back," and particulars of this vessel will now be described.

Its capacity should be about six barrels per quarter of malt brewed, but the contents may vary considerably. For instance, if there be a regular and good supply of liquor, the back need not be so large as when the supply is uncertain, although it is well to have the back large enough. It should not be unnecessarily large, as it must be borne in mind that fresh liquor is generally the best for brewing. It must be constructed of wood or iron. Generally it is made of wood if indoors, and of cast iron if out of doors. Wrought iron is also occasionally used, but for very small backs only, which are to be placed indoors. Wrought or cast iron may be galvanized, but it is very seldom desired. A few cast-iron backs have been enamelled inside, but since this about doubles the cost, they are not in request.

In position, the water back should be the highest utensil in a brewery, and command every other. It is not uncommon to make it serve as a roof to a part of the building; but some brewers object to the liquor being exposed to the atmosphere, and will have it covered or indoors. When it is outside there must be access to it from the brewery for cleaning, &c. It must on no account be placed over another utensil in such a position that the steam arising from the lower will strike against the bottom of the liquor back. This applies particularly to the iron backs, as the steam would readily condense against the cold iron and become a great nuisance. In proportion the width is frequently about half the length; but length and width are not important. It should not be very deep—say 3 or 4 feet—because, as it is the highest utensil, it requires multitudinous supports, and if shallow, of course the weight is spread over a larger surface.

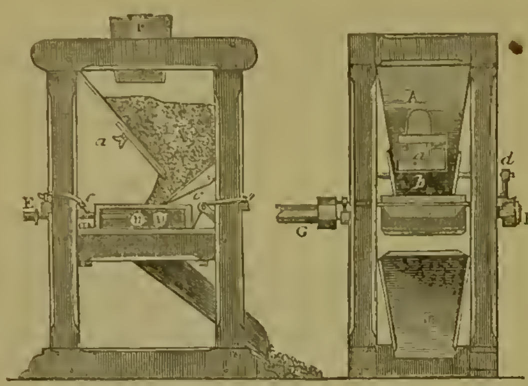
The liquor back, when full of water, weighs about 4 cwts. per barrel if made of wood or wrought iron, and about 5 cwts. per barrel if in cast iron. When constructed of cast iron it should be made in plates of a convenient size, bolted together with wrought-iron screw bolts. When made of wood the best Dantzic fir should be used.

In places where there is a deficiency in the supply of liquor cold enough for refrigerating and attemperating, machines for the artificial production of cold are now frequently made use of. (See Ice-making Machines.) Sometimes these machines are used for making ice, which is put into the liquor to make it colder; but, on account of the large quantity of cold liquor that is required, it is more common to cool the liquor direct, reducing it in temperature about 20° Fahr. (11° C.)—thus largely economizing the quantity of liquor required for refrigerating.

Grinding.—Little need be said on grinding, in addition to what has been already stated under Alcohol. It is essential to have the natural cohesiveness of the grain destroyed in such a way that the water may have free access to every particle of it, in order to insure the entire extraction of the valuable constituents. Of the various methods resorted to, whether by reducing the grain between stones in the ordinary way, or by steel mills, wherein it is cut or torn in the same manner as coffee is ground, or by crushing between rollers, that mode is preferable which disintegrates the grain completely, and loosens the husk from the fleshy parts without separating the two.

A moment's consideration will show that these conditions are not fulfilled by either of the first two methods; and it is only by the use of rollers that the malt can be properly prepared. A secondary advantage is gained in the facility with which the mash is racked off, leaving but little of the extract in the grains. When it is ground fine, the malt, besides being apt to "set" and form a mucilaginous magma, retains much of the liquor, which cannot be

Fig. 7. Fig. 8.

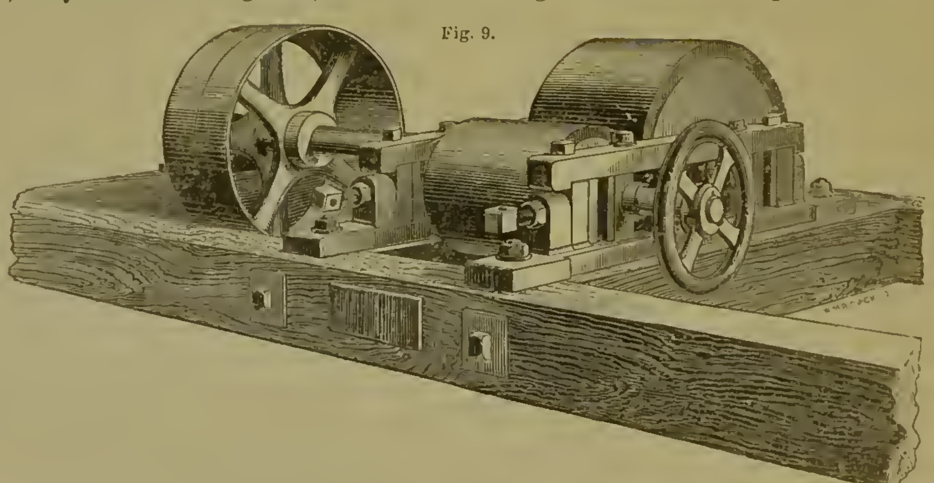


removed except by long washing, thus rendering the worts dilute, and exposing them to the danger of acetification in the succeeding treatment. When the particles of the grains still adhere, though their natural texture is broken, each shell forms, as it were, a filter, through which the clear liquor percolates readily, leaving any matter which might be taken up mechanically behind. If the grain be torn or sliced, as by the steel cutting mills, in which the contents of the grain remains to some extent adhering to the husk in its natural state, considerable loss will be sustained, for the water will not penetrate these parts during the period usually allowed for mashing. That this is the case is evident from the well-known fact, that dried malt will float on water for a period of twenty-four hours, without absorbing enough of the liquid to increase its gravity sufficiently to cause it to sink.

The annexed cuts, Figs. 7, 8, represent, in front and lateral section, the cylinder malt mill: I is a sloping trough, through which the malt passes from its bin or floor to its hopper, A, whence it is shaken between the iron rollers, B, D, working at their extremities in bearers or sockets of hard brass, fitted securely into the side frames, which are also of iron: E is a screw passing through the upright, and serving to force the bearer of one roller towards that of the other, so as to bring them nearer together when the malt is wanted in a finer state of division: G is the square end of the axis, by which one of the rollers is turned. The other rotates by means of a pair of equal-toothed wheels, H, fitted to the opposite extremities of the axes of the cylinders: *d* is a catch working into the teeth of a ratchet wheel, not shown in the engraving, on the end of the rollers. The lever, *c*, comes in contact with the trough, *b*, at the bottom of the hopper, giving it a shaking motion, which discharges the malt upon the rollers from the side sluice, *a*. *e e* are scraper-plates, the edges of which, pressing on the rollers, remove adhering matter, and thus keep them clean.

The malt is in the best breweries now ground, or more properly speaking crushed, in the mill sketched at Fig. 9. It is made to pass between cast-iron

Fig. 9.



rollers with smooth surfaces, the rollers varying in size and proportion according to the quantity to be crushed; but it may be taken that the malt crushing rolls should be capable of crushing as many quarters per hour as are mashed in one operation. Their dimensions therefore vary from 8 inches wide and 8 inches diameter to any required size.

It is now generally preferred to make one roll about twice the diameter of the other, and to drive only the larger roll, the smaller roll revolving by the friction of the malt passing between the two. These rollers are furnished with set screws so as to regulate the space between them for the passage of the malt (Fig. 9). It is most essential that good smooth surfaces be maintained on the rolls, or otherwise the crushing will be imperfect, and the uncrushed malt unproductive.

The rolls should be furnished with a wire screen

to take out the dust, stones, &c., that may be in the malt. They should not be driven too fast, or the grist will become heated. In some breweries the malt is screened into different sizes, and each size is crushed by a separate pair of rolls differently set, so as to insure every grain being crushed to the same extent.

In large breweries, where the malt is frequently stored in bins, a good adjunct is KING's patent grain measurer, which registers the quantity of malt passed through it. It consists of a revolving wheel or drum with compartments.

The position in the brewery of the malt rolls is important, as the malt hopper (generally made of wood) should be commanded by the malt store, so that the malt can be shot directly into the hopper, and run into the rolls. Where the malt rolls are obliged to be above the store, it is necessary to have an elevator, or Jacob's ladder, to carry up the malt. The elevator consists of an endless band of leather, upon which are fastened metal buckets, running on pulleys driven by steam power, the band being inclosed by wood or iron casing. When the malt has to be conveyed some distance horizontally to the malt rolls, it is generally done by means of an iron screw revolving in a tube, the screw being formed by an iron shaft having a blade of sheet iron running the whole length; such an one may be seen in ALCOHOL, Plate 1.

When the malt has passed through the rolls it is called grist, and usually runs into a wooden hopper called the "grist case," erected over the "mash tun." The grist case, like the malt hopper, is generally made of wood, the large ones sometimes of iron; it should contain sufficient material for one brewing. Where the malt rolls have been placed too low to command the grist case there must be an elevator, as above described, to raise the grist to the required height.

It may be mentioned that where the malt store is in the upper part of the building, it should be furnished with a sack tackle for raising the sacks of malt. In large breweries several pairs of rolls are used, as it is not found advisable to make rolls to crush more than 30 quarters per hour; and in such cases it is usual to keep one or more pairs of rolls especially for crushing the black malt used for porter and stout.

Mashing.—Mashing is the most important part of brewing, as by it the brewer extracts the saccharine principle from the malt; and hence his profit entirely depends upon the success of this operation.

The process of mashing depends on the action of diastase upon starch, under the influence of heat and moisture. (See ALCOHOL.) Roughly speaking, diastase has the power of converting about 2000 times its own weight of starch into grape sugar.

The theories which have been broached from time to time as to the action of diastase upon starch have been very various. MÜLDER, whose researches on the chemistry of brewing were made some years ago, supposed that the action of this soluble albuminous matter was to convert the starch into dextrine in the first place, and then afterwards to convert some of that dextrine already formed into sugar. SCHWARZER more recently took the same view—viz., that dextrine is first of all formed, and then afterwards converted into sugar. He states that at temperatures above 65° to 70° C. the ratio of glucose to dextrine is as 1 to 3; whereas below 60° C., that is below 140° Fahr., the ratio is about equal — viz., 1 glucose to 1 dextrine. MUSCULUS, on the other hand, has concluded from his researches that 3 parts of starch, when thoroughly acted upon by diastase, produced 2 of dextrine and 1 of sugar. C. O'SULLIVAN, the scientific adviser of Messrs. BASS & Co., asserts that neither dextrine or glucose are formed at all, but a species of sugar (maltase) having a structure intermediate between that of grape sugar and starch.

Diastase is by long digestion dissolved out in greater quantity from the malt at low temperatures than at high, and it has been observed that the temperatures at which its solution is most complete is between 100° to 140° Fahr. (37°·7 to 60° C.), whereas the temperature at which it is most active in converting the soluble matters of the mash into a more sugary or saccharine form is much higher.

At low temperatures dextrine is uniformly produced along with the sugar, and then as the temperature gradually rises, more and more of the sugar is obtained, until a point is arrived at, at which this action upon dextrine can go no further.

Before stating the particular operations of mashing, it may be well to make a few allusions to the quantity of extractive matter usually obtained from malt, and the problem of its thorough exhaustion, a point which is the grand aim of mashing. From the analyses given of malt, as well as those of barley, it will be seen that the available constituents of the former amount to 78·3 per cent. when dried by the ordinary means; and as a quarter of good malt generally weighs 352 lbs., it follows that 275·5 lbs. of these are available valuable matters, the remainder being water and husk. It is to be borne in mind that all this quantity is not saccharine matter, but that there exists in it a variable proportion of albumen and gluten; these, however, are abstracted to a great extent in the mashing, and are afterwards removed, as will be seen further on. Now, the best practical results average about 90 to 95 lbs. per qr., as shown by the specific gravity saccharimeters; but as every unit of this number equals 2·6, or, according to DRING and FAGE, and CASARTELLI, 2·7 lbs. of real extract, it is evident that the total of the valuable ingredients is 234 to 249 lbs.; for $90 \times 2{\cdot}6 = 234$; and $95 \times 2{\cdot}6 = 249$; but if the calculation be made according to the latter authorities, the produce will be 243 and 256·5 lbs.

It is, however, easy for the brewer to ascertain when he is successful in his exhaustions, and also what ought to remain after fermentation to give body to his product. He should also be able to find the amount of extract in a wort from the gravity of the liquor, as indicated by the saccharimeter, without the necessity of recurring to the tables, or sliding rules accompanying them; for it frequently happens that errors creep into such calculations, and

the results they point to are sometimes greater, sometimes less, than the real amount contained in the worts. To do this, all that is required is to multiply the indication by 2·6, or 2·618—2·7 according to CASARTELLI—and the product will be the real weight of extract in each barrel of the wort.

By this means the total extract per quarter in the first mash may be found, and by deducting it from 275·5 the remainder is what is left in the grains to be extracted in the next mash; knowing this, the amount of liquor employed may be regulated accordingly, so as to obtain a dense wort, and thereby avoid the danger of acetification, to which dilute worts expose the products.

The process of mashing differs somewhat according to the use to which the worts are to be put. It is the object of the vinegar maker to obtain a wort of such strength, or containing so much saccharine matter, as will give a product affording, after the fermentation and oxidation of the alcohol, about 5 per cent. of acetic acid. The distiller desires to extract the valuable principles entirely, and produce a wort which will completely ferment, leaving as little saccharine matter as possible in the liquor. The brewer wishes to have a dense extract (which shall neither acetify nor, at the same time, be wholly converted into alcohol); and so to restrict the amount of alcohol that the liquor will merely communicate a pleasant hilarity to those partaking of it, reserving the greater portion of the malt extract for communicating to his beer richness, unctuousness, and flavour. If he leaves these particulars, or any one of them, unattended to, his beverage will become very quickly distasteful to his customers.

The first important point with the brewer is the complete abstraction of the soluble substances in his malt; the next, and not less important point, is that he is to effect it with the smallest possible quantity of liquor, it being understood that he must be rigorously careful to prevent any acidification. Six or seven barrels of water per quarter of malt are generally sufficient for the exhaustion, of which $2\frac{1}{4}$ to $3\frac{1}{4}$ barrels are lost in the after operations of boiling and fermenting.

MUSPRATT thinks that too much water is used. He says that it is plain that the diastase and gluten of the malt are capable of transforming a much larger quantity of starch into sugar than what is present, and it is no less obvious that the water employed is sufficient to hold in solution a far greater proportion of the saccharine substance than it can possibly meet with in any brewing operation; it therefore follows that the methods adopted are defective, inasmuch as an unnecessarily large quantity of fluid is used to attain the results which, according to the known properties of the constituents, might be accomplished with less.

It is well known that the diastase of the malt is most active when the liquid is rather dilute, and the temperature is between 160° and 170° Fahr. (71°·1 to 76°·6 C.); the latter might be injurious at the outset in a brewing operation, but the former, or even 165° Fahr. (73°·8 C.), can be applied with safety. Hence it is apparent, that by sustaining an equalized temperature, and with the use of a moderately large quantity of water, the conversion of the starch into glucose will be complete, and that it can be almost entirely extracted in the first solution, leaving nothing in the first mash for the subsequent sparging, but to wash out that portion imbibed by the grains. By accomplishing this with 4 to 5 barrels, instead of 6 to 7, the brewer would derive material advantage, as the "lengths" which are at present employed, and subsequently expelled by evaporation, &c., would to a great extent be unnecessary. Another inducement to the adoption of means for obtaining dense worts is one which brewers must necessarily value, namely, the production of sound beer; for it is impossible to brew a good beverage from an inferior wort; and when the latter is weak, the tendency to acetification is far greater than when a heavy extract is used.

Considerations like these ought to be sufficient to check the practice of varying, in almost every brewing, the manner of mashing; now applying a low temperature, then a high one, but always using repeated mashings, which entail the trouble of continued boiling afterwards, and ultimately impair the quality of the beer.

The chief point is to apply so much water, and maintain such an initial temperature, as will, on sufficient time being allowed, completely disintegrate the grains at one mashing, and leave nothing for the subsequent abstractions but what remains of the first in their pores. This is the highest perfection in mashing.

The temperature of the liquor which is mixed with the malt varies between 160° and 170° Fahr. (71°·1 to 76°·6 C.); in some cases even more. This variation of temperature, however, depends upon several conditions. First, on the amount of radiation that may take place from the mash tun itself; secondly, on the specific heat of the malt used, because this varies in different malts; and, thirdly, on the particular class of ale which is to be brewed. If it be a strong ale less hot water will be used than if it be a weak one.

The English method of infusion depends upon using a high initial temperature. The following table by Dr. GRAHAM shows the amount of the several constituents named after three hours' mashing:—

ENGLISH MASHING PROCESS AT A HIGH INITIAL TEMPERATURE.

	140° Fahr.	150° Fahr.	160° Fahr.	170° Fahr.	175° Fahr.
Wt. of Extract per c.	70·00	69·75	69·00	67·25	—
Draff,........ "	22·28	23·65	23·96	24·39	—
Glucose,...... "	33·35	30·50	29·41	20·79	15·62
Dextrine,..... "	32·50	34·11	34·33	—	—
Soluble starch, "	none.	traces.	small quantity.	41·13	—

From the above it may be seen that the higher the temperature the less sugar is there in the extract, and there is still more unconverted starch.

The usual routine of mashing will now be described.

The first point to be attended to in a brewery is scrupulous cleanliness, particularly in the various

vessels, lest any albuminous substances should be left adhering to them, which, by entering into a putrescent fermentation, might thus communicate the same to the worts, and prove highly detrimental. It is hoped that the importance of this requirement is well understood, since its being overlooked would ruin a brewery, however much skill might be displayed in other ways. The only means of securing this point are to wash the various backs, boilers, coolers, and other utensils, occasionally with lime-water, made by macerating a bushel of quicklime in about twenty barrels of water, or to have all the vessels made of metal; it would be desirable, also, to keep any backs, or other vessels which may not be constantly in use, full of water till such time as they are needed. The manager should be likewise careful to keep the mash-tun perfectly clean; for if any grains should remain in it after a previous brewing, their albuminous contents might suffer decomposition, and give rise to or induce an acid fermentation, which, if absorbed, would prove destructive in the succeeding brewing. Too much precaution cannot be used in guarding against these causes of mischief, which, though apparently trifling in themselves, so operate as to cause the brewer heavy losses.

Unless the brewer mashes every day, it would be well that he should attend to all the preliminaries required for the proper execution of his task previously to the day of brewing; the coppers should be charged with liquor, and sufficient fuel to sustain the fire for heating the materials should be provided. Where the mashing is performed daily, these requirements are secured as a matter of course.

The work, on the day of brewing, should be vigorously proceeded with as early as possible, and especially in hot weather, which demands on the part of the operator greater vigilance and care to secure success.

It is customary to have a journal, wherein the temperature of the atmosphere, the quantity of malt, the heats of the different mashings, as well as of the tap, and other particulars, are recorded.

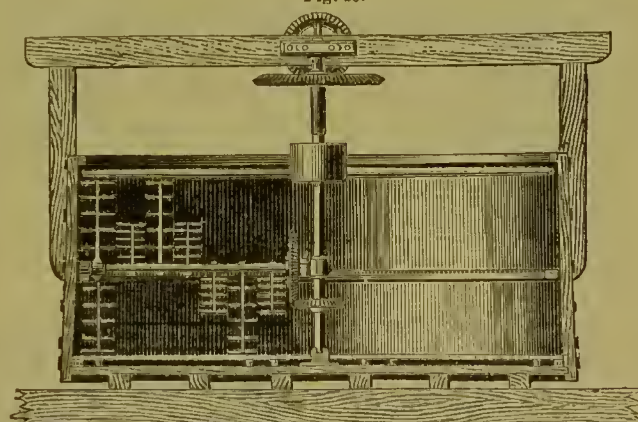
The malt, of whatever description it may be, should be ground if possible the day previous to mashing, but at most it should not be retained longer than three or four days crushed before it is submitted to the mash-tun; for if long kept it will attract moisture from the atmosphere, become heated through the effects of an internal decomposition of the saccharine substance, and render the beer bad in quality.

As previously noticed, the ground malt is usually conducted, in well-regulated breweries, by an Archimedean screw to the hoppers over the tun in the mashing-room, which serve as magazines for it, and whence it is let into the latter when fit, and macerated with water. There are two modes of accomplishing this mixture—one by manual labour and the other by machinery; but the latter is preferable on all occasions, as it is much more effectual in breaking up the masses of malt which are apt to form in the water. Indeed, very often serious injuries arise from the "balling" of the malt, when the mashing has been carelessly performed with oars, or too large a quantity of water has been run upon it at first; for besides being wasted by enveloping a certain volume of air, and being but partially wetted and surrounded by an elevated temperature, the agglomerated portions very quickly generate acetic acid, unless they are rapidly broken up.

Although it has been generally supposed that to get a good extract it was necessary to well mash or beat the liquor and malt together; nevertheless, within the last few years, many brewers have been of opinion that a perfect saturation of the malt is sufficient, although there are some who do not agree with this latter view.

The mashing is performed in a vessel called a mash-tun by means of machinery, the various forms of which will be presently described. The mash-tun itself should contain from 3 to $3\frac{1}{2}$ barrels per quarter of malt to be mashed. It must be of a

Fig. 10.



cylindrical form, and from 3 to 6 feet deep, according to the capacity required. It is constructed of English oak staves with Dantzic fir bottom, or of cast iron put together in the same manner as described for the cold-liquor back. In position the mash-tun must be commanded by the hot-liquor copper, or other utensil in which the liquor is heated; and in its turn must command the vessel in which the wort is boiled, unless the wort be, as is sometimes the case, pumped up into the wort-boiling vessel.

Many years ago mashing was done by simply stirring by hand with wooden oars, which was a very imperfect method; much of the "goods," as the wetted grist is termed, was frequently left untouched, and consequently was imperfectly productive. The form of the mashing machine then introduced (patented by Matterface in 1807) has been used with very few alterations down to the present time (Fig. 10). It consists of a vertical shaft driven by steam power from above, and working in a footstep with gun-metal bearing bolted to the centre of the bottom of the mash-tun inside; half way down the mash-tun, inside, is bolted a toothed rack, in which works a

toothed pinion on end of an iron shaft, and the other end of the shaft works in a gun-metal bearing attached at its proper height to the vertical shaft. This horizontal shaft, or "rake shaft," as it is commonly termed, works round the mash-tun by the vertical shaft revolving, and in its turn is made to revolve by a pair of bevel toothed wheels, one on the vertical shaft and one on the rake shaft. The rake shaft is provided with a number of wrought-iron oars, or rakes, generally about 8 inches wide, and by these means the mashing is effectually accomplished. Although some other forms of internal mashing machines have been used, they have not been generally adopted.

In a few instances brewers objecting to iron have gone to the great expense of having the mashing machine made entirely of gun metal.

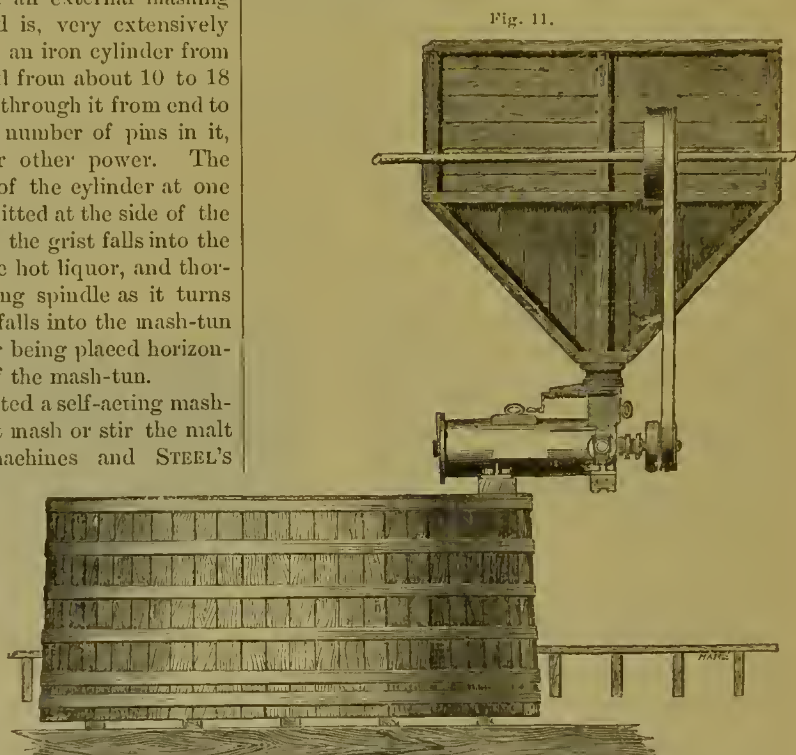
In 1853 W. STEEL patented an external mashing machine which has been, and is, very extensively used (Fig. 11). It consists of an iron cylinder from about 3 feet to 6 feet long, and from about 10 to 18 inches in diameter. Running through it from end to end is a spindle with a large number of pins in it, which is driven by steam or other power. The grist is admitted into the top of the cylinder at one end, and the hot liquor is admitted at the side of the cylinder at the same end. As the grist falls into the cylinder, it is there met by the hot liquor, and thoroughly mashed by the revolving spindle as it turns in the cylinder, after which it falls into the mash-tun at the other end—the cylinder being placed horizontally on the top of the edge of the mash-tun.

In 1863 C. MAITLAND patented a self-acting mashing apparatus, which does not mash or stir the malt as the internal mashing machines and STEEL'S machines do, but simply thoroughly saturates the malt on its way to the mash-tun; many brewers believing this to be all that is necessary for obtaining a good extract. This very simple apparatus has ever since its introduction been extensively used (Fig. 12). It consists of a copper double cylinder from 16 to 36 inches high, and from 6 to 12 inches in diameter. This cylinder is fixed vertically to the bottom of the grist case. The hot liquor is admitted through the outer cylinder, and the inner cylinder being furnished with a number of perforations, and a jet throwing upwards from the bottom, the grist, as it falls through, comes in contact with numerous streams of hot liquor, thus insuring that every grain is thoroughly saturated with liquor at the same temperature.

With the internal mashing machines the whole of the grist is turned into the mash tun before the mashing commences. The hot liquor is then admitted at the bottom of the mash-tun, and when a sufficient quantity has been allowed to pass in, the machine is put into motion. It follows that in using the internal mashing machine every grain does not come in contact with liquor of the same temperature, as the latter is considerably cooled by coming in contact with the cold grist at the bottom of the mash-tun before it wets the upper portion of the grist. This, of course, is obviated by using an external mashing machine like STEEL'S or MAITLAND'S, either of which is very frequently used in addition to the internal mashing machine. The great advantage of MAITLAND'S mashing machine is its simplicity and lowness of cost; having no moving parts there is nothing to get out of order, and not requiring any motive power, the cost of the driving gear required for other machines is saved.

Other external mashing machines have been introduced during the past few years; but not having met with the success of STEEL'S or MAITLAND'S, need not be described here.

Fig. 11.



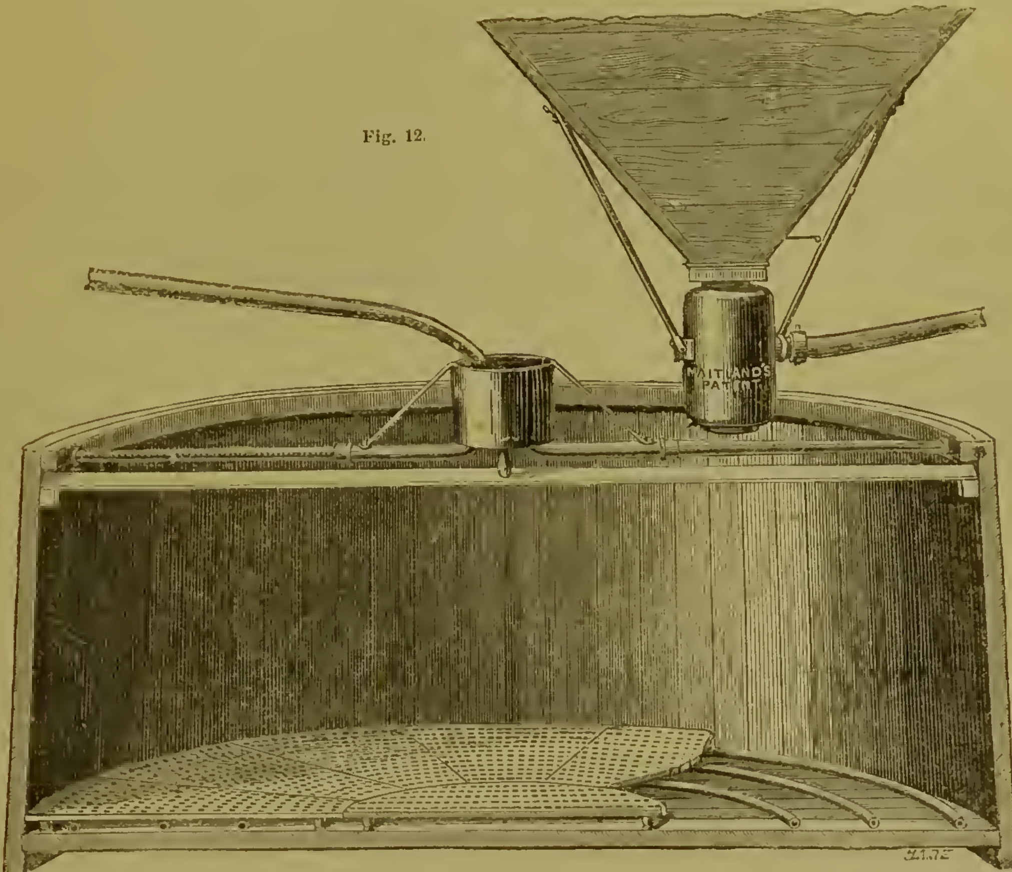
The mash-tun is provided with a false bottom to strain the wort from the grains. The extract is called wort when it is drawn from the mash-tun, and the malt then left behind is called grains. The false bottom is usually made of cast iron in plates of a convenient size, and about ⅜ths of an inch thick, having perforations about ⅛th of an inch in diameter, and about 1 inch apart all over, and countersunk on the under-side. The false bottom is usually placed about 2 inches above the bottom of the mash-tun. Originally the perforations used to be cast, but they were then so irregular in size that it has been found much better to drill them, which is now invariably done. False bottoms are sometimes made of cast gun metal or wrought copper, and these are now in much greater request than they used to be.

The bottom of the mash-tun is frequently fitted

with a grain door, through which the grains are thrown out when done with.

The wort is drawn off from the mash-tun by means of several cocks or taps, called "spend taps." About

Fig. 12.

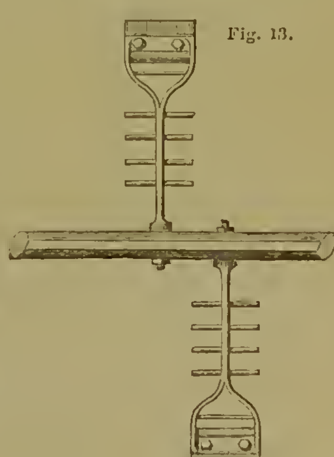


four to six are usual, so as to draw from all parts of the tun. As it is important to the brewer to get the wort off bright, having several "spend taps" enables him to close one or more from which the wort may not be running bright.

After the first mash is completed a further quantity of hot liquor is put over the top of the "goods" by means of a "sparger." This sparger revolves on the well-known principle of Barker's mill. It has a copper basin in the centre, into which the hot liquor is admitted, thence passing through two or more perforated arms extending to the sides of the mash-tun. Where there is an internal mashing machine the basin is made so that the upright shaft of the mashing machine passes through it, and the basin runs on wheels fixed to a carriage on the upright shaft. Where there is no internal mashing machine the basin turns on a pivot (Figs. 10 and 12), or sometimes on a joint somewhat like a ball and socket joint.

When the wort is drawn from the mash-tun it runs into a vessel called the "underback," which need not be of sufficient capacity to hold anything like the whole quantity of wort, as it is from the "underback" at once run or pumped up into the wort copper for boiling. As it is always desirable to maintain the temperature of the mash and the wort uniform, a mashing attemperator is frequently applied to the mash-tun. A very effective form of mashing attemperator, and the simplest, is a coil of copper pipe placed underneath the false bottom (Fig. 12), the steam being passed through it as required. The same thing is often applied to the underback, so that the temperature of the wort may be maintained on its way to the copper. The mashing machine is sometimes driven from below with a stuffing box through the bottom of the mash-tun; but this method should not be adopted unless unavoidable. Small sizes may be worked by hand. Large size machines have two or more rake shafts.

Fig. 13.



After the first mash a second is made in a similar manner. All the remaining saccharine matter is by this means extracted from the malt.

Recently a patent was taken out by P. R. Couron (Fig. 13) for a very simple but very useful addition to the ordinary internal mashing machine. To the

ends of the ordinary rakes are fixed flexible strips or brushes of pliable material, vulcanized india-rubber being found the most suitable, which in their revolution sweep aside and effectually stir up the grain in the mash-tun.

It is well known that, unless the malt is coarsely ground, the goods are liable to settle on and clog the holes of the false bottom, thereby preventing the even flow of the taps, and proper percolation of the sparged liquor through the goods, thus causing delay, and in the summer time endangering the soundness of the wort. On the other hand, the malt coarsely ground will never yield its full extract. COUROX'S patent enables the rakes to act really upon the false bottom of the mash-tun and sweep aside the grain, thus clearing the holes and insuring a more thorough mixing of the contents of the mash-tun.

After mashing the tub is carefully covered down, to preserve the heat of the mash and exclude the air from the wort as much as possible; and having been allowed to rest for about two hours, it is then drawn off to the copper; an operation which must be performed with great care, to insure the liquor being perfectly bright, and free from any solid particles of malt.

At this stage the sweet liquor is apt to enter upon the vinous fermentation, and thence to pass to the acetic, to prevent which the temperature is raised to ebullition, and the hops added; meantime the partly exhausted malt, after the whole of the liquor has been drawn, is to be subjected to a second operation. For this purpose the tub is uncovered, and a fresh quantity of water, the amount of which is regulated according to the density of the first worts, or the quantity of the matter yet unextracted, is turned on at the proper heat, and mashed by one of the foregoing machines; the tub is then covered, and the whole allowed to digest for one hour, or less, according to circumstances, and then drawn off as before. By proper attention the whole of the requisite constituents of the malt should be taken up by these two mashings; sometimes, when the mash is very stiff, a third sparge is let in upon the grist to exhaust it, but the product is used only for *table beer*.

Having, in the above short sketch, given an outline of the whole course of mashing, a few remarks in explanation of the process will now be added. It is the custom with a great many brewers to let the water into the tun at a higher degree of heat than is required by the mash, and allow it to cool down to the proper temperature before the malt is introduced. Others, again, admit the malt and heated water simultaneously, while the machine, being put in motion, mixes them thoroughly. In the latter instance, it is plain that the heat of the liquor must be much higher than the initial heat at which the constituents of the malt should be extracted (namely, 160° Fahr. (71°·1 C., or thereabouts), for the water communicates part of its heat to the mash-tun, as likewise to the goods, and thus causes a decrease of 20° or 30° Fahr. (11° to 16°·5 C.) or more, according to the state of the weather. It is equally obvious that the mixing of the malt and a liquor of 180° or 190° Fahr. (82°·2 to 87°·7 C.) is unadvisable; for although, in the event of mixing them, a mean temperature of 158° or 160° Fahr. (70° to 71°·1 C.) may result, yet the starch, albuminous, and glutinous part, cannot but be rendered insoluble in those portions with which the solution comes in contact at the commencement.

On the contrary, if the water be poured in at 170° Fahr. (76°·6 C.), or under the mean, after fifteen or twenty minutes it will be far below that at which the diastase and gluten are most active in converting the starch into glucose. The conclusions from these observations evidently favour the heating of the mash-tun with the water, and when it has been reduced to 165° (73°·8 C.), or between this and 170° Fahr. (76°·6 C.), to admit the malt from the hopper, and mash rapidly. In this case the malt is the only body which can abstract the heat, and the slight elevation of the temperature supplied for meeting this decrease does not react so injuriously upon the goods as in the first case.

Others, again, turn on as much water at a low degree of heat as will moisten the malt completely, and cause it to swell, after which the remaining quantity of water required to make up the wort is let on at 190° to 194° Fahr. (87°·7 to 90° C.), and mashed in the usual way. This method is said to be advantageous. First, by lessening the tendency to set. Second, by giving the diastase greater scope for acting upon the starch, since the greater part of the sugar is dissolved out in the first wetting, and the residual portion is more permeable to the solution, which, having a temperature of about 165° Fahr. (73°·8 C.) as its mean, is very effective in exhausting the goods.

It should be remembered, however, that diastase is very soluble, and that it is wholly, or to a great extent, removed with the sugar, leaving only the gluten in proximity with the starch to effect its solution. During the subsequent part of the operation, when the water of a higher temperature is poured on, many authorities of long experience affirm that the particles of this active principle are placed at such a distance from the starch that the diastase cannot exert the same influence as if it and the starch were exhausted at the same time.

The quantity of water which is usually taken varies from 1½ to 2½ barrels per quarter of grist for the first mash, according to the system of working followed by different persons; but if the mean temperature could be sustained throughout the mashing, it is quite evident that 1 barrel, 6 firkins, which weighs about 630 lbs., would be even more than sufficient to exhaust the quarter of malt of its soluble ingredients, consisting, as they do, principally of glucose or saccharine matter, which requires only 1·33 parts of cold water for its solution, and much less when the temperature is raised as in mashing.

From all these peculiarities, it seems that the general defects of mashing are:—1. Inefficient extraction in consequence of the gluten and portions of the

starch of the grain forming a gelatinous mass which envelopes the starch and sugar, and does not allow the water to flow off, in consequence of too elevated a temperature. 2. Non-conversion of the starch into glucose in consequence of too low a temperature. In the subsequent operations this kind of wort is prone to acidify and spoil, particularly if the time of mashing and tapping be long.

It is evident that the maintenance of a due degree of heat, and the employment of the proper amount of liquid so as to have a dense wort, are the two chief points which should attract the brewer's attention; and if he could surmount all the difficulties arising from long custom, based upon imperfectly understood principles, and make the attempt to add science to his working practice, it is evident that a considerable part, if not all the loss which is at present so generally sustained by brewers, might be converted into profit.

The following table relating to the temperature and time of the standing of the mash, &c., is by LEVESQUE, and throws considerable light on this point. It should be remarked, however, that the heat of the mash water varies according to the malt employed, that for pale malt being the lowest, whilst for high-coloured it may be poured on at a much more elevated temperature. The degrees marked are Fahrenheit:—

Temperature of the air at mashing.	CLASS I. Heat of the mash 140° to 145°. Firkins per quarter 6.	Time of standing of the mash.	Temperature of the air at mashing.	CLASS II. Heat of the mash 145° to 147°. Firkins per quarter 7.	Firkins per quarter 8.	Time of standing of the mash.	Temperature of the air at mashing.	CLASS III. Heat of the mash 144° to 146°. Firkins per quarter 9.	Firkins per quarter 10.	Time of standing of the mash.	Temperature of the air at mashing.	CLASS IV. Heat of the mash 143° to 145°. Firkins per quarter 11.	Firkins per quarter 12.	Time of standing of the mash.
		h. m.				h m.				h. m.				h. m.
10°	197·00	4·00	10°	189·00	184·00	3·00	10°	178·00	175·00	2·00	10°	172·00	170·00	1·00
15	195·17	4·00	15	187·42	182·59	3·00	15	176·84	173·92	2·00	15	171·00	169·19	1·00
20	193·34	4·00	20	185·84	181·18	3·00	20	175·68	172·84	2·00	20	170·00	168·28	1·00
25	191·51	4·00	25	184·26	179·77	3·00	25	174·52	171·76	2·00	25	169·00	167·37	1·00
30	189·68	4·00	30	182·68	178·36	3·00	30	173·36	170·68	2·00	30	168·00	166·46	1·00
35	187·85	4·00	35	180·10	176·95	3·00	35	172·20	169·60	2·00	35	167·00	165·55	1·00
40	186·02	4·00	40	179·52	175·54	3·00	40	171·04	168·52	2·00	40	166·00	164·64	1·00
45	184·19	4·00	45	177·94	174·13	3·00	45	169·88	167·44	2·00	45	165·00	163·73	1·00
50	182·36	4·00	50	176·36	172·72	3·00	50	168·72	166.36	2·00	50	164·00	162·82	1·00
55	180·53	4·00	55	174·78	171·31	3·00	55	167·56	165·28	2·00	55	163·00	161·91	1·00
60	178·70	3·40	60	173·20	169·90	2·45	60	166·40	164·20	1·50	60	162·00	161·10	0·55
65	176·87	3·20	65	171·62	168·49	2·30	65	165·24	163·12	1·40	65	161·00	160·19	0·50
70	175·04	3·00	70	170·04	167·07	2·15	70	164·08	162·04	1·30	70	160·00	159·28	0·45
Heat of the tap from 141° to 146°.			Heat of the tap from 143° to 145°.				Heat of the tap from 142° to 144°,				Heat of the tap from 141° to 143°.			

In the first column under each class of this table, the temperature of the atmosphere at the time of mashing is noted; the next columns are the degrees at which the water should stand to bring the mash to the points at the head of the columns, and the figures at the foot specify the temperature at which the tap stands.

Mashing in this way often causes much variation in the results, owing to the dryness or particular quality of the malt, and the state of the atmosphere. When very dry malt is used, on mixing it with water of a certain heat the resulting temperature is not an arithmetical mean of the two, but is somewhat higher, owing to an elevation of a few degrees, caused by the conversion of starch into sugar, and its solution in water. This fact should be kept in mind when adding the water for the mash, and its temperature regulated accordingly.

When barley is mixed with twice its volume of water, the heat arising from this mixture will be about the mean temperature; but if pale malt be similarly treated the result will exceed the mean; and if highly dried brown malt be taken, the thermometer will indicate a rise of 40° Fahr. (22° C.) over the mean: this elevation always takes place in the first mash, during which the conversion of the starch proceeds with the greatest activity. Such results do not, however, always attend the mixing of the water and malt, as when the latter has stood some time after grinding, it absorbs water from the atmosphere and becomes "mellowed," in which case the development of the heat is not so great as when the goods are perfectly dry; hence, when mashing such mellowed malt, the liquor ought to be somewhat hotter than that which is used with the fresh.

Another circumstance which influences the heat of the mash is the bulk of materials taken; thus the temperature, when only 2 barrels of water per quarter are employed, needs to be higher than if 3 are taken, notwithstanding that the rise by mixing is greater in the first instance.

DONOVAN, speaking of the temperature to be employed in mashing, lays down the following as a general rule:—For well-dried pale malt, provided the atmosphere does not exceed 50° Fahr. (10° C.), the heat of the first mash water may be, but should never exceed, 170° Fahr. (76°·6 C.); that of the second, 180° Fahr. (82°·2 C.); and for the third, 185° Fahr. (85° C.), but never beyond.

It may be observed that the danger of acetification of dense worts at a temperature of 160° Fahr. (71°·1 C.), is not incurred by a slight prolongation of the time of mashing and setting, as might be at first apprehended, for both are unfavourable to the change. (See ACETIC ACID and VINEGAR).

Now, if the agitation of the goods by the machine be continued only for a short time, say from half an hour to an hour, the question might be asked:—Will

the conversion of the starch be completed during that time? Again, during the subsidence of the grains and other matters distributed through the liquor by the mashing, will the whole of the starch become saccharified? The answer to each of these questions being in the negative, it must be concluded that the shortness of the time of mashing, and the ineffectual methods adopted for maintaining a suitable temperature, are the chief causes which operate against the obtaining of dense worts, and in favour of acetification. Allowing that the mashing is successful in discharging the whole of the starch and other valuable matters from the grain, and that nothing is left in the shell (which, however, is not so); on the suspension of the motion in the mash-tun the chief part of the starch remains unacted upon, and as the grains fall to the bottom they carry considerable portions of the goods with them out of the reach of the solution. The increased gravity of the liquors, in consequence of the portion of glucose that is formed, also precipitates and hastens the descent of the yet unconverted starch, leaving in a short time the upper part of the liquid clear, and of a very low density. Certainly, the quantity of wort imbibed by the grains assists in the change into sugar, but the transformation is not nearly so effectual as if the contents were disseminated through the bulk of liquid taken for the mash. Another consideration which tends to show that the prolonging of the mash, provided the due degree of heat is kept up (as by a suitable attemperator), would not cause the time of "setting the tap" to extend beyond the usual period allowed in the generality of breweries is, that the chief part of the starch being saccharified whilst the liquid is in agitation, the time afterwards necessary for the clearing of the wort would not be so long as in ordinary cases; for the grains, the sinking of which is to be effected, being dense and in large masses, would readily subside, and the delay caused by the very slow descent of the minute particles of starch still floating in the liquor to the bottom of the tun would be avoided.

Dr. CHARLES GRAHAM recently made a series of experiments to see the amount of action that took place at different temperatures in a given time. He says:—Firstly, I took cold water at 60° to 70° Fahr. (15°·5 to 21°·1 C.), and raised it up to the temperatures indicated in the table below, and kept them at those respective temperatures for two hours. At the end of that time I digested the first at 100° Fahr. (37°·7 C.), and found 24 per cent. converted into sugar; when it was raised to 110° Fahr. (43°·3 C.), 30 per cent.; at 120° Fahr. (48°·8 C.), 32 per cent.; at 130° Fahr. (54°·4 C.), 35 per cent.; at 140° Fahr. (60° C.), 37½ per cent.; and the dextrine also increased.

	100° F.	110° F.	120° F.	130° F.	140° F.
Glucose, per cent.,...	24·19	30·00	32·17	35·71	37·50
Dextrine and starch,..	34·00	29·25	27·33	24·11	26·70

Showing a gradual increase in the amount of sugar formed. The total amount of extract gradually increased, but at 140° Fahr. (60° C.), instead of being a gradual process, there is a sudden leap, and at that temperature there is a much greater amount of extract.

The next point that occurred to me was to test the truth of the German brewers' theory about the range of temperature of 165° to 167° Fahr. (73°·8 to 75° C.), being the most favourable for the conversion of starch and dextrine into sugar. The mashing heat was started on the principle of a low initial temperature raised up in the first hour to 100° Fahr. (37°·7 C.). It was then kept for two hours at a temperature of 140° to 145° Fahr. (60° to 62°·7 C.), and finally was heated up to 165° to 167° Fahr. (73°·8 to 75° C.).

	2 hrs. at 165° to 167° F. Per Cent.		6 hrs. at 165° to 167° F. Per Cent.	
Wt. of Extract,	70·25		70·55	
Draff, ...	21·58		20·71	
Glucose,......	39·06	=Starch 62·52	41·67	=Starch 62·51
Dextrine, ...	27·36		25·00	

The extract in the first case is considerable in amount; indeed, very much higher than any obtained in the English infusion process. We have no less than 39 of sugar and 27 of dextrine. In the second, where it was carried on for six hours at this range of temperature, the ratio of sugar and dextrine increases, that is to say, the dextrine diminishes and the sugar increases, though, by adding the two together, they are practically identical. If one-tenth is taken from the whole of the numbers representing the glucose, the remainder gives the amount of starch that it originally came from.

But there is a different ratio between the sugar and the dextrine. Therefore, by prolonging the temperature at this higher stage, the German brewer is correct in his idea of getting more sugar, because 2·36 of dextrine have been converted into 2·61 of sugar. Having thus proved the correctness of his idea, I proceeded next to test what would be the result if I were to take the extreme case, which of course no practical brewer ever uses, a temperature of 175° Fahr. (79°·4 C.). I took that as a crucial test. I took a sample of malt and heated it gradually during 60 minutes from the cold up to 175° Fahr. It was then kept at that excessively high temperature for a period of two hours, when the amount of sugar formed was 32 and the dextrine 30.

	(1.)	(2.)
Wt. of Extract, per cent.,................	69·70	69·10
Draff, "	23·51	23·35
Glucose, "	32·10	32·05
Dextrine, "	30·29	30·60

Therefore, practically, the two results were identical. In other words, in that short time a ratio is obtained quite as high as is found in the English infusion method.

Thus, these two points being settled, viz., the advantage of a low initial temperature and the advantage of a high final temperature, I proceeded then to try to discover what would be the best way to arrange the mashing temperature. First of all, I heated malt from the cold up to 85° Fahr. (29°·4 C.) for one hour; I then carried it on from 85° to 140° Fahr. (60° C.) for one hour; and then for three hours it was kept at 140° Fahr. and then boiled. In the second series it was raised during the first hour from the cold up to 140° Fahr.; it was then allowed to remain for two hours at that tem-

perature, and then it was raised very rapidly to 175° Fahr. (79°·4 C.), when it was boiled. In the third experiment it was raised in the first hour up to 140° Fahr.; it remained during the second hour at that temperature; and then in the third hour it was raised to 175° Fahr. (79°·4 C.).

	(1.) Per Cent.		(2.) Per Cent.		(3.) Per Cent.	
Wt. of Ex.,	71·50	..	71·06	..	69·00	
Draff, ...	21·70	..	22·35	..	22·61	
Glucose,...	41·66	=starch 62·59	40·07	=starch 62·51	35·72	=starch 60·76
Dextrine, ..	25·09		36·45		28·65	

The first two yield practically the same results, making the same deduction as before by taking one-tenth from the determination of glucose, which will give us the starch from which it is derived. Those numbers added together are 62·59 and 62·51, showing practically the same amount of extract, whereas in the other case we have only 60·76 if the same deduction is made from the glucose. So that there has been in the rapid increase of temperature a very great falling off in the production of extract, and there has also been a great falling off in the ratio of the sugar to the dextrine. I think from these few experiments it may be seen, by comparing the numbers together, that the more gradually the temperature is raised the more perfect will be the extract, and the higher will be the sugar-forming ratio.

The limits of the varying ratios cannot exceed 2 of dextrine to 1 of sugar, or, on the other hand, 2 of sugar to 1 of dextrine, and besides depend on the varying conditions which may be taken as the functions of the experiment.

1. The ratios depend on the relative masses of starch and diastase. The more starch the less sugar will be formed in a given time.

2. It depends on the temperature of the infusions.

3. It also depends on the quantity of water employed. An infusion made with a small quantity of water will, in a given time, produce less sugar than when the infusion has more water, because the production of sugar from dextrine requires the absorption with the molecule of so much water." (*Soc. of Arts Jour.* vol. xxii.)

Dr. GRAHAM proposes to increase the ratio of sugar by starting with a low initial temperature, in order that a large amount of the active principle diastase may be dissolved, and then raising the temperature of the mash up to 140° to 150° Fahr. (60° to 65°·5 C.), by adding hot "piece liquor," or passing steam into the underback by means of a coil. After digesting for some time at this temperature it should be raised to 165° Fahr. (73°·8 C.).

With high initial temperatures, as mashing is at present performed, the ratio of sugar is readily increased by adding cane sugar, which is for the most part converted into glucose by the diastase if added in the mash-tun; or it is converted into diastase if boiled with the wort by the free acids. On account of the large amount of albuminous matter contained in cane sugar, which tends to promote a putrescent fermentation, the cane sugar is commonly converted into grape sugar (invert sugar, dextri-glucose and levo-glucose) by dilute sulphuric acid. After conversion the free acid is thrown down by chalk, calcium sulphate (gypsum) being formed, a small percentage of which, if left with the sugar, is far from injurious to the wort.

The amount of dextrine may be augmented by adding thoroughly dried unmalted grain to the mash. Dextrine, when in large quantity after the worts are fermented, gives the soundness of flavour which is much esteemed in stout and porter, and certain kinds of ale.

C. O'SULLIVAN has made some interesting researches on the transformation products of starch, in the course of which he observed that from 100 parts of starch was formed 100 parts of a sugar, intermediate in molecular structure between grape sugar and starch; to this he has given the name of maltase. (*Chem. Soc. Journal*, vol. xxv.)

Maltase is white, soluble in water, but less soluble in alcohol than glucose; it withstands the action of diastase even when digested with it for a prolonged period. It is, however, readily converted by dilute sulphuric acid at the temperature of boiling water into ordinary glucose.

Having thus far spoken of the data and principles by which to regulate mashing at this stage of the process—for the first mash is the most important—the method of drawing off the wort, or "setting the tap," as it is called, together with the extraction of the portion of the goods still retained in the grains by the operation of sparging, or after-mashing, will next be considered.

In "setting the tap," most brewers recommend that the goods should be drawn off at the same degree as is indicated at the conclusion of the mashing, whatever the variety of malt worked upon. Those who may not be very conversant with the real nature of the subject, and may have doubts as to the quality of the malt, its newness, hardness, weight, slackness, or dryness (all of which require a variation of the heat, or of the quantity of liquor), if they are already acquainted with the final heat of the first mash of a good operation, have only to raise the tap to this point, and copy it in their subsequent mashing.

The first mash being completed, and the underback wherein the sweet worts are received being thoroughly clean, the tap is turned on gently at first, and afterwards more quickly, till the liquor runs half bore. Unless great care be exercised the worts will not flow off bright and clear as they should do, and particles of the more finely divided grain, which are sometimes productive of inconvenience in the succeeding operations, will percolate through.

If the process has been successful the wort will be of the same shade of colour as the malt employed; it should have a tough and close head of a silvery whiteness, passing, when examined in the vessel, to a delicate cream on the surface. It should be full, effervescing, and fine flavoured, considerably more so than the succeeding extract or after mash, in consequence of the more mucilaginous and resinous parts of the grist not being abstracted. When the

heat of the mash is too high, it is observed that the silvery white head has a tinge of brown, and that this colour is deeper in proportion to the greater elevation of the mash above the proper degree. Again, if the heat be too low, the head is less close, firm, bright, and lively in flavour. With very low heats the head will not stand, but flies off instantly, and the taps are thick and muddy. This kind of wort, on being exposed to the air, readily enters into decomposition and turns acid.

When the whole of the extract has been drained off, the proper quantity of liquor to be used in removing the residuary portion, which is retained mechanically by the grist, as well as any starch which may still be present, is turned on. If the preceding details have been carefully attended to, the quantity of the starch will be inconsiderable. Many persons employ from three-eighths to one-half the quantity of water taken from the first extract, and add it at 185° Fahr. (85° C.), or 10° Fahr. (5°·5 C.) over that at which the first mash was made, and treat the goods as in the first mash, except that the time is only a quarter or one-half that allowed to the first. The precautions which have already been mentioned should be observed in setting the tap; and the worts should be conveyed to the boiler together with the first portion.

By an economical disposal of the temperature and duration of the mash, as well as the proportion of the liquor taken, the residual starch in the grains will be inappreciable; but when, as in many cases, the operations are conducted in a haphazard, unscientific, and often in an irrational way, there sometimes remains after the second mash as much as from 8 to 10 lbs. per barrel extract, and it even happens that this is not wholly removed by a third watering. This product, however, is coarse and ill-flavoured, owing to the great proportion of bitter resin and mucilage intermixed with it, and which hitherto had remained in the grains, the temperature not having been retained at that degree at which the diastase could exert its influence in saccharizing these substances. In order to avoid the accumulation of such degenerating constituents in the third and fourth mash, the heat should be 10° to 12° Fahr. (5°·5 to 6°·6 C.) higher in the second than in the first mash, if products are run into the boiler as the strong wort; if three mashings are to be made for the same, a difference of 5° or 6° (2°·7 to 3°·3 C.) in each is sufficient, making the final one at 160° Fahr. (71°·1 C.).

It is to be observed that the custom of mashing so repeatedly is at variance with the opinions of most chemists who have investigated the subject of brewing.

Another method is also adopted for abstracting the residuary matters in the grist, after the first mash is completed, which is called "sparging," from the circumstance that the liquid is sprinkled on the goods from numerous outlets. It is said to be very beneficial in its results, particularly when the whole of the wort is intended for the strong or the better quality of beer. The method of sparging is as follows:—When the tap has been set for drawing off the first wort, hot liquor, of the same temperature as the preceding mash, is sprinkled on the malt from a machine constructed thus: a perforated tube is laid upon a bar, the two being placed horizontally in the tun, and resting upon a pin in the centre, over these a receiving vessel is placed to supply the tube with water. The perforations extend to the whole length of the two or three arms of the tube, so that the liquid flows out horizontally, but in opposite directions; and through the effect of the force of this efflux, together with the centrifugal motion communicated by the current coming from the receiving vessel, the pipe is kept rotating, and the liquor is dispersed equally over the goods. Some brewers, instead of the tube, use a cover, which they place over the liquor, and direct the stream upon it; the first method seems, however, to be more efficient.

Many persons do not set the sparger till one-fourth, one-half, or even three-fourths of the strong extract has been drawn off; but when the liquid is sprinkled on gently—as it must be from the perforated tubes—there need be no apprehension of the wort being too dilute; and the good which is done by displacing the quantity of the stronger mash imbibed by the malt, as also by exhausting from the grist the residual saccharine matter, without taking up the resinous constituents, is an undoubted recommendation; besides which, when the chief part of the first mash is drawn off before the sparging, the grains accumulate in too dense a layer on the bottom.

To many brewers whose routine of working is based on old established practice this mode may appear ruinous, as their after mashings contain 6 to 10 lbs. of extract per barrel, which are calculated to be as valuable as an equal proportion of the first wort; but if a proper course of mashing be adopted, the whole of the valuable constituents will be taken up in the first wort, and what remains embedded in the grist can be removed by washing or sparging, in the manner which has just been described. A dense and valuable wort will be thus obtained, and the cost of subsequent concentration will be much lessened.

It is necessary to have the sparging continued without intermission, till the whole of the soluble matters is removed, using only as much liquor as is necessary to make up the proper lengths.

The grains left after mashing, or when the whole of the starch has been removed, are used to feed swine and cattle. They contain gum, some of the nitrogenous constituents of the barley, together with a certain amount of cellulose, which is as nourishing to animals as an equivalent weight of the original unmalted grain. In addition to these there is a further quantity of mucilage, which will contribute in the animal economy to effect the same purposes and ends as starch.

SACCHAROMETRY.—The brewer estimates the quantity of sugar in his wort by its density. The knowledge of the gravity of the beer after fermentation, so as to ascertain the quantity of spirit and saccharine matters contained in it, is also of importance.

TABLE BY DR. URE SHOWING THE QUANTITY OF SUGAR IN POUNDS AVOIRDUPOIS CONTAINED AT SUCCESSIVE DEGREES OF SPECIFIC GRAVITY, AT 60° FAHR. (15·°5 C.).

Specific Gravity.	Lbs. per Gallon.	Extract by weight in 100.	Specific Gravity.	Lbs. per Gallon.	Extract by weight in 100.	Specific Gravity.	Lbs. per Gallon.	Extract by weight in 100.	Specific Gravity.	Lbs. per Gallon.	Extract by weight in 100.
1·000	0·0000	·0000	1·076	1·9928	·1828	1·152	4·0342		1·228	6·0642	
1·001	0·0255	·0026	1·077	2·0197	·1851	1·153	4·0611		1·229	6·0925	
1·002	0·0510	·0051	1·078	2·0465	·1873	1·154	4·0880		1·230	6·1205	
1·003	0·0765	·0077	1·079	2·0734	·1896	1·155	4·1148		1·231	6·1474	
1·004	0·1020	·0102	1·080	2·1006	·1918	1·156	4·1319		1·232	6·1743	
1·005	0·1275	·0128	1·081	2·1275	·1941	1·157	4·1588		1·233	6·2012	
1·006	0·1530	·0153	1·082	2·1543	·1963	1·158	4·1857		1·234	6·2280	
1·007	0·1785	·0179	1·083	2·1811	·1985	1·159	4·2128		1·235	6·2551	
1·008	0·2040	·0204	1·084	2·2080	·2007	1·160	4·2502		1·236	6·2822	
1·009	0·2295	·0230	1·085	2·2359	·2029	1·161	4·2771		1·237	6·3093	
1·010	0·2550	·0255	1·086	2·2627	·2051	1·162	4·3040		1·238	6·3362	
1·011	0·2805	·0280	1·087	2·2894	·2073	1·163	4·3309		1·239	6·3631	
1·012	0·3060	·0306	1·088	2·3161	·2095	1·164	4·3578		1·240	6·3903	
1·013	0·3315	·0331	1·089	2·3438	·2117	1·165	4·3847		1·241	6·4152	
1·014	0·3570	·0356	1·090	2·3710	·2139	1·166	4·4115		1·242	6·4401	
1·015	0·3825	·0381	1·091	2·3987	·2161	1·167	4·4383		1·243	6·4650	
1·016	0·4180	·0406	1·092	2·4256	·2183	1·168	4·4652		1·244	6·4902	
1·017	0·4335	·0431	1·093	2·4524	·2205	1·169	4·4923		1·245	6·5153	
1·018	0·4590	·0456	1·094	2·4792	·2227	1·170	4·5201		1·246	6·5402	
1·019	0·4845	·0481	1·095	2·5061	·2249	1·171	4·5460		1·247	6·5651	
1·020	0·5100	·0506	1·096	2·5329	·2270	1·172	4·5722		1·248	6·5903	
1·021	0·5351	·0531	1·097	2·5598	·2292	1·173	4·5983		1·249	6·6152	
1·022	0·5602	·0555	1·098	2·5866	·2314	1·174	4·6242		1·250	6·6402	
1·023	0·5853	·0580	1·099	2·6130	·2335	1·175	4·6505		1·251	6·6681	
1·024	0·6104	·0605	1·100	2·6404	·2357	1·176	4·6764		1·252	6·6960	
1·025	0·6355	·0629	1·101	2·6663	·2378	1·177	4·7023		1·253	6·7240	
1·026	0·6606	·0654	1·102	2·6921	·2400	1·178	4·7281		1·254	6·7521	
1·027	0·6857	·0678	1·103	2·7188	·2421	1·179	4·7539		1·255	6·7800	
1·028	0·7108	·0703	1·104	2·7446	·2443	1·180	4·7802		1·256	6·8081	
1·029	0·7359	·0727	1·105	2·7704	·2464	1·181	4·8051		1·257	6·8362	
1·030	0·7610	·0752	1·106	2·7961	·2486	1·182	4·8303		1·258	6·8643	
1·031	0·7861	·0776	1·107	2·8227	·2507	1·183	4·8554		1·259	6·8921	
1·032	0·8112	·0800	1·108	2·8485	·2529	1·184	4·8802		1·260	6·9201	
1·033	0·8363	·0825	1·109	2·8740	·2550	1·185	4·9051		1·261	6·9510	
1·034	0·8614	·0849	1·110	2·9001	·2571	1·186	4·9300		1·262	6·9822	
1·035	0·8866	·0873	1·111	2·9263	·2593	1·187	4·9552		1·263	7·0133	
1·036	0·9149	·0897	1·112	2·9522	·2614	1·188	4·9803		1·264	7·0444	
1·037	0·9449	·0921	1·113	2·9780	·2635	1·189	5·0054		1·265	7·0751	
1·038	0·9768	·0945	1·114	3·0045	·2656	1·190	5·0304		1·266	7·1060	
1·039	1·0090	·0969	1·115	3·0304	·2677	1·191	5·0563		1·267	7·1369	
1·040	1·0400	·0993	1·116	3·0563	·2698	1·192	5·0822		1·268	7·1678	
1·041	1·0653	·1017	1·117	3·0821	·2719	1·193	5·1080		1·269	1·1988	
1·042	1·0906	·1041	1·118	3·1080	·2740	1·194	5·1341		1·270	7·2300	
1·043	1·1159	·1065	1·119	3·1343	·2761	1·195	5·1602		1·271	7·2601	
1·044	1·1412	·1089	1·120	3·1610	·2782	1·196	5·1863		1·272	7·2902	
1·045	1·1665	·1113	1·121	3·1871	·2803	1·197	5·2124		1·273	7·3204	
1·046	1·1918	·1136	1·122	3·2130	·2824	1·198	5·2381		1·274	7·3506	
1·047	1·2171	·1160	1·123	3·2399	·2845	1·199	5·2639		1·275	7·3807	
1·048	1·2424	·1184	1·124	3·2658	·2865	1·200	5·2901		1·276	7·4109	
1·049	1·2687	·1207	1·125	3·2916	·2886	1·201	5·3160		1·277	7·4409	
1·050	1·2940	·1231	1·126	3·3174	·2907	1·202	5·3422		1·278	7·4708	
1·051	1·3206	·1254	1·127	3·3431	·2927	1·203	5·3681		1·279	7·5007	
1·052	1·3472	·1278	1·128	3·3690	·2948	1·204	5·3941		1·280	7·5307	
1·053	1·3738	·1301	1·129	3·3949	·2969	1·205	5·4203		1·281	7·5600	
1·054	1·4004	·1325	1·130	3·4211	·2989	1·206	5·4462		1·282	7·5891	
1·055	1·4270	·1348	1·131	3·4490	·3010	1·207	5·4720		1·283	7·6180	
1·056	1·4536	·1372	1·132	3·4769	·3030	1·208	5·4979		1·284	7·6469	
1·057	1·4802	·1395	1·133	3·5048	·3051	1·209	5·5239		1·285	7·6758	
1·058	1·5068	·1418	1·134	3·5326	·3071	1·210	5·5506		1·286	7·7048	
1·059	1·5334	·1441	1·135	3·5605	·3092	1·211	5·5786		1·287	7·7331	
1·060	1·5600	·1464	1·136	3·5882	·3112	1·212	5·6071		1·288	7·7620	
1·061	1·5870	·1487	1·137	3·6160	·3132	1·213	5·6360		1·289	7·7910	
1·062	1·6142	·1510	1·138	3·6437	·3153	1·214	5·6651		1·290	7·8201	
1·063	1·6414	·1533	1·139	3·6716	·3173	1·215	5·6942		1·291	7·8482	
1·064	1·6688	·1556	1·140	3·7000	·3193	1·216	5·7233		1·292	7·8763	
1·065	1·6959	·1579	1·141	3·7281	·3214	1·217	5·7522		1·293	7·9042	
1·066	1·7228	·1602	1·142	3·7562	·3234	1·218	5·7814		1·294	7·9321	
1·067	1·7496	·1625	1·143	3·7840	·3254	1·219	5·8108		1·295	7·9600	
1·068	1·7764	·1647	1·144	3·8119	·3274	1·220	5·8401		1·296	7·9879	
1·069	1·8033	·1670	1·145	3·8398	·3294	1·221	5·8680		1·297	8·0150	
1·070	1·8300	·1693	1·146	3·8677	·3314	1·222	5·8962		1·298	8·0448	
1·071	1·8571	·1716	1·147	3·8955	·3334	1·223	5·9242		1·299	8·0719	
1·072	1·8843	·1738	1·148	3·9235	·3354	1·224	5·9523		1·300	8·1001	
1·073	1·9116	·1761	1·149	3·9516	·3374	1·225	5·9801				
1·074	1·9385	·1783	1·150	3·9801	·3394	1·226	6·0081				
1·075	1·9653	·1806	1·151	4·0070		1·227	6·0361				

Reference has already been made to the means whereby the worts may be tested, and the amount of saccharine matter ascertained, by the specific gravity of the liquor as shown by the saccharometer; but as the liquor at this stage is usually between 150° and 160° Fahr. (65°·5 to 71°·1 C.), the indication which it gives is only the apparent density, since, by expansion, the bulk of the solution is considerably increased; and therefore the amount of solid extractive matter, in any given volume of the liquor, is much less than what the same bulk would show at 60° Fahr. (15°·5 C.), the barometer being at 29·5 or 30 inches.

A variety of saccharometers are in use; the one chiefly employed in the trade, and by the Excise, is that constructed by R. B. BATE. This instrument shows the value of wort and low wines, the excess in the weight of a beer barrel of wort above that of water, the solid extract or the true pounds weight per beer barrel, beer gallon, wine gallon, and imperial gallon, and the proportion of solid extract by weight. It is usually made of metal, has five floats answering to the different strengths of the wort, and one to indicate which of the poises will suit for each occasion, mostly on the same plan as SIKES' alcoholometer. (See ALCOHOL.). The instrument is accompanied by a book, wherein are copious explanations and directions for using it, together with tables of gravity and strengths per barrel for every degree of specific gravity, from ·995 to 1·150, and also every alternate degree of temperature, from 50° to 150° Fahr.

Dr. URE, who in 1830 experimented on this subject. states that the specific gravity of the solid dry extract of malt is 1·264, and the specific volume 0·7911, that is, ten pounds of it will occupy the volume of 7·911 of water. When this extract is dissolved in its own weight of water, the density of the resulting liquid, by calculation, ought to be 1·1166, whereas, by experiment, it proved to be 1·216, thus showing that a considerable condensation of volume had taken place in the act of combination with the water.

The following table, showing the relation between the specific gravity of the solutions of malt extract and the quantity of matter they contain, illustrates the above statement:—

Malt Extract. Water.	Malt Extract in 100.	Sugar in 100.	Specific Gravity.
600 + 600	50·00	47·00	1·2160
600 + 900	40·00	37·00	1·1670
600 + 1200	33·33	31·50	1·1350
600 + 1500	28·57	26·75	1·1130
600 + 1800	25·00	24·00	1·1000

Regarding the saccharometric tables constructed by BATE and others on solutions of sugar, and not upon those of extract of malt, URE remarks that they agree pretty well with the former, but differ materially from the latter.

On page 299 is given DR. URE'S saccharometric table for a simple syrup.

Apart from the foregoing consideration, there is an important circumstance which must be taken into account in ascertaining the gravity, namely, the different expansions of bodies at various degrees of temperature, from 32° Fahr. (0° C.) to their boiling point. When many liquids are heated from 32° Fahr., or their point of greatest density, to 212° Fahr. (100° C.), considerable difference is observed in this respect; for instance, the dilatation of alcohol is much greater than that of water, and this again than mercury, and so of numerous other liquids. The amount of expansion of different liquids in passing through one hundred and eighty degrees Fahrenheit (100° C.), that is, from 32° to 212° Fahr., is found by experiment to be—

Alcohol, ...	$\frac{1}{9}$	Oil of turpentine, ...	$\frac{1}{14}$
Nitric acid, ...	$\frac{1}{6}$	Sulphuric acid, ...	$\frac{1}{17}$
Fixed oils, ...	$\frac{1}{12}$	Water, ...	$\frac{1}{23}$
Ether, ...	$\frac{1}{14}$	Mercury, ...	$\frac{1}{55}$

It may be well to illustrate the meaning of the above by showing the difference in volume of water from 32° to 212°, as given by several chemists who have investigated the subject.

There is one remark, however, which is deserving of being made, for the sake of those who may not be conversant with such subjects, namely, that heat communicated to the bottom of liquids is readily diffused through the whole body; not, however, by radiation, as is the case with solids, but by the dilatation of the inferior particles, which renders them specifically lighter than those above them, on which account they ascend, their place being occupied by other globules; these, again, receiving warmth and ascending like the preceding. Thus, by the constant exposure of fresh portions of water to heat, and the motion produced in the liquor by their rarefaction, the whole bulk is brought to that degree beyond which any further application of heat would destroy the limits within which its density and liquidity remain, and the fluid would become a vapour or gas. But when the heat is applied to the surface of a liquid the supernatant particles only receive the rays, these expand, are rendered lighter, and continue to float upon the denser, which are consequently only very gradually warmed. This slowness of acquiring heat from the surface led RUMFORD to deny that water, or fluids generally, had any power of conducting it; it is, however, now known that liquids do conduct heat, though in a degree far inferior to solids.

Science has converted this phenomenon to highly beneficial uses in many departments of industrial progress. The thermometer, with all its inestimable benefits, is based upon it, and at the present day the application of expansion of bodies by heat to the requirements of manufactures, trade, and navigation, commands no small consideration in contributing to the wealth of nations.

According to KOPP, water expands when heated from 32° to 212° Fahr., 0·042986 of its volume, as will be seen from the annexed table of the expansion of water from the freezing to the boiling temperature, the volume at 0° C., or 32° Fahr., being taken as unity:—

Temp. Cent.	Temp. Fahr.	Volume.	Temp. Cent.	Temp. Fahr.	Volume.
0°	32°	1·000000	21°	69·8°	1·001776
1	33·8	0·999947	22	71·6	1·001995
2	35·6	0·999908	23	73·4	1·002225
3	37·4	0·999885	24	75·2	1·002465
4	39·2	0·999877	25	77·0	1·002715
5	41·0	0·999883	30	86·0	1·004064
6	42·8	0·999903	35	95·0	1·005697
7	44·6	0·999938	40	104	1·007531
8	46·4	0·999986	45	113	1·009541
9	48·2	1·000048	50	122	1·011766
10	50·0	1·000124	55	131	1·014100
11	51·8	1·000213	60	140	1·016590
12	53·6	1·000314	65	149	1·019302
13	55·4	1·000429	70	158	1·022246
14	57·2	1·000556	75	167	1·025440
15	59·0	1·000695	80	176	1·028581
16	60·8	1·000846	85	185	1·031894
17	62·6	1·001010	90	194	1·035397
18	64·4	1·001184	95	203	1·039094
19	66·2	1·001370	100	212	1·042986
20	68·0	1·001567			

The preceding table shows the degree of contraction which water undergoes when heated from 32° Fahr. (0° C.), to its point of greatest density, which is stated as 39·2° Fahr. (4° C.). From this point to the normal temperature of 60° Fahr. (15°·5 C.), the expansion of a volume of water is 0·000894, and from this to 158° Fahr. (70° C.), ·021475 of its original volume. Now, a given bulk of liquid, having solid bodies, such as mineral or organic salts, dissolved in it, does not increase or contract in the same proportion when heated from 32° to 212° Fahr. (0 to 100° C.), as does pure water, in consequence of the solid matter not being so expansible as the liquid. From this it follows that dense worts will not dilate or contract so much as those which are more dilute. On examining worts of high temperatures, it is necessary to find and allow for the increase of weight consequent upon the contraction of any given bulk of liquid, when cooled from a higher to a lower degree of heat.

According to Bate's tables, the allowance which should be made for every ten degrees between the normal points, 60° and 150° Fahr. (15°·5 to 65°·5 C.), is as follows:—

Saccharometric Gravity.	70°	80°	90°	100°	110°	120°	130°	140°	150°	Sum.
10	1·0	1·2	1·5	1·7	1·9	2·1	2·3	2·5	2·8	17·0
50	1·2	1·4	1·6	1·8	2·1	2·3	2·5	2·7	3·0	18·6
100	1·4	1·6	1·8	2·0	2·2	2·5	2·7	2·9	3·2	20·3
150	1·6	1·8	2·0	2·2	2·4	2·7	2·9	3·2	3·4	22·2

The subjoined table by Bate will answer the purposes of the ordinary brewer; and where the corresponding degree does not occur, a correct fraction may be attached at an average, founded on the following facts. When a liquid, the specific gravity of which is 1·000 at 60° Fahr., is heated to 78° Fahr. (25°·5 C.), the instrument will sink two divisions below the true gravity as found at 60° Fahr. (15°·5 C.), and if the temperature be elevated to 93° Fahr. (33°·8 C.), it will sink four divisions, and so on. Any solution, therefore, which has been heated to these points, and tested with the hydrometer or saccharometer, will manifest a much higher density when cooled down to 60° Fahr. (15°·5 C.), the normal standard temperature; thus, if there be three liquids at the temperatures of 124°, 92°, and 79° (51°·1, 33°·3, and 25°·5 C.), and the instrument be dropped into them, it will sink in the first ten, in the second eight, and in the third six divisions, lower than it would in the same were they cooled down to 60° Fahr. (15°·5 C.); hence, when testing the liquors heated to these degrees, it is necessary to add the numbers ten, eight, six, &c., to the apparent densities, in order to find the real gravity at the standard of 60° Fahr. (15°·5 C.).

Specific Gravity at 60° Fahr.	Apparent gravities giving the same density at the accompanying heats as the first column at 60°.									
	Ap. sp. gr.	Degrees.	Ap. sp. gr.	Degrees.	Ap. sp. gr.	Degrees.	Ap. sp. gr.	Degrees.	Ap. sp. gr.	Degrees.
1·000	0·998	79·00°	0·996	93·00°	0·994	105·00	0·992	115·50°	0 990	125·20°
1·010	1·008	78·00	1·006	92·00	1·004	104·00	1·002	114·50	1·000	124·00
1·020	1·018	78·00	1·016	91·33	1·014	103·00	1·012	113·50	1·010	122·80
1.030	1·028	77·33	1·026	90·66	1·024	102·50	1·022	112·50	1·020	122·00
1·010	1·038	76·66	1·036	90·00	1·034	101·50	1·032	111 50	1·030	120·80
1·050	1·048	76·00	1·046	89·33	1·044	100·66	1·042	111·00	1·040	120·00
1·060	1·058	76·00	1·056	88·66	1·054	100·00	1·052	110·00	1·050	118·80
1·070	1·068	75·33	1·066	88·00	1·064	99·00	1·062	109·00	1·060	118·00
1·080	1·078	74·66	1·076	87 33	1·074	98·00	1·072	108·00	1·070	116·80
1·090	1·088	74·66	1·086	86·66	1·084	97·50	1·082	107·00	1·080	116·00
1·100	1·098	74·00	1·096	86·00	1·094	96·50	1·092	106·50	1·090	114·80
1·110	1·108	74·00	1·106	85·50	1·104	96·00	1·102	105·50	1·100	114·00
1·120	1·118	73·50	1·116	85·00	1·114	95·50	1·112	104·50	1·110	113·20
1·130	1·128	73·33	1·126	84·50	1·124	94·50	1·122	104·00	1·120	112·40
1·140	1·138	73·00	1·136	84·00	1·134	94·00	1·132	103 20	1·130	111·40
1·150	1·148	72·66	1·146	83·50	1·144	93·50	1·142	101·40	1·140	110·80

The following is a theorem for reducing the gravities of hot worts. To unity, or 1, representing the standard of water, add 0·1 for every twenty-five points of gravity indicated by the instrument, and 0·01 for each degree of temperature above 60, and multiply the sum by ten times the latter number for the correction.

Example 1.—Let the apparent density be 6, and the temperature 92°, then $(1 + {\cdot}32) \times 3{\cdot}2 = 4{\cdot}224$, which, added to the original 6, gives 10·224.

Example 2.—Apparent gravity 27, temperature 124°.

Here $(1{\cdot}1 + {\cdot}64) \times 6{\cdot}4 = 1{\cdot}74 \times 6{\cdot}4 = 11{\cdot}136$, and $11{\cdot}136 + 27 = 38{\cdot}136$, results which agree with those of Bate.

Boiling.—Boiling of the worts is avowedly practised with the intent of removing the excess of nitrogenous matter; for if this were permitted to remain it would undergo the putrid fermentation, and completely destroy the whole product; but boiling is also

reputed to give to the liquor a pleasant flavour, and render it more wholesome. The most satisfactory recommendations in its favour, however, are that it diminishes the liability to acidity by expelling the contained air. When those matters which are subject to acetification are in a measure excluded from the atmosphere, the liquor remains sound for a long time.

Boiling is also requisite for the expulsion of the excess of liquor used in the mashing, as well as for the transformation of any starch which might still remain intact into glucose and dextrine.

There is a further important object for which the worts are boiled, namely, the extraction of the valuable bitter and aromatic principles of the hops, whereby the flavour of the liquor is improved and an agreeable aroma imparted to it.

The hops not only impart a bitter aromatic taste, but also a keeping quality, as they counteract the natural tendency of the beer to become sharp—an effect partly attributable to the precipitation of the albumen and starch by their resin and tannic acid, and partly to the anti-fermentable properties of their lupulin and other constituents.

Various opinions have been set forth regarding the necessity, the efficacy, and the injuriousness of boiling; generally speaking, the idea is that from the manner in which it is usually conducted it acts prejudicially, inasmuch as by it the most prized material of the hops—the odoriferous oil—is dissipated, and too much of the disagreeable principle and tannin extracted, so that the bitterness and astringency become too powerful. Those who condemn boiling altogether should study its anti-putrescent effects, especially where albuminous and other substances, analogous to those in the extract, are present. Boiling has the effect of expelling air from the liquid, and coagulating the albumen; the matter being thus excluded from air or oxygen, may be preserved without undergoing putrefaction.

It is well known that nitrogenous substances, which will otherwise very readily putrefy, may be retained for a considerable period in a wholesome state by expelling air and keeping them afterwards in exhausted receivers. By abstracting the air contained in the wort, and guarding against its reabsorption by keeping the liquor in exhausted vessels, it may be preserved during any length of time without giving rise to acid products. The same result may be attained even in presence of air by retaining it at a low degree of cold; but upon the application of a heat ranging from 70° to 90° Fahr. (21° to 32°·2 C.), with exposure to the influence of the air, the oxidation of the compounds present follows, and finally acetic acid, with the products usually formed in putrefying bodies, results. These observations strongly support PASTEUR's theory of fermentation by accession of germs.

Were there only saccharine matter present, the liquor might be preserved a length of time at any temperature, without risk of the acidification of the worts occurring; but the proneness of the nitrogenous impurities to *eremacausis* (LIEBIG's term for oxidation, slow combustion, *anglice*, decay) opens the way for the mucilage and sugar to pass partly into the lactic and partly into the vinous fermentation, and then, by a further state of chemical decomposition, into acetic acid, when it is needless to say the whole of the materials are spoiled.

Thus far in reference to the keeping of the worts and their protection from decomposition by boiling, its immediate effect will now be taken into account.

Evidently this operation tends to, or has for its object, the removal of albumen and any other matters which, if permitted to remain in the wort, would readily absorb oxygen on being left in contact with the air, and cause the chemical changes which brewers have so much reason to apprehend; but in effecting this purpose it is argued that, besides a valuable portion of the glucose and dextrine being abstracted, the essential oil of the malt is almost entirely volatilized in consequence of the long boiling at the high temperature at which this is done. That portions of the sugar are removed, or rendered unavailable to some extent, cannot be doubted; for it is well known that when vegetable extracts, and indeed most organic compounds, some of which are as permanent in their nature as sugar, are boiled for a long time, a gelatinous substance, similar in character to woody fibre, forms in the solution at the expense of a portion of the compound, which must have suffered decomposition. Such is the case in the open copper of the brewer, especially when the air is not excluded; but as to the oil inherent in the malt being dissipated, this is a new and gratuitous supposition which has no foundation, for the oil of the grain in its natural state is not expelled at a temperature of 212° Fahr. (100° C.).

From the above considerations the correct conclusion to be drawn appears to be, that were it not for the necessity of removing the nitrogenous matters, the boiling of the worts might be dispensed with. It has been urged that though distillers do not boil their worts, yet the attenuation in the succeeding fermentation is very complete. This must be granted; but it should be borne in mind that they immediately remove the spirit from the gross nitrogenous products by distillation, lest the latter, if permitted to remain with it, should change it into acetic acid by regular and well-defined processes which have been already discussed. (See ACETIC ACID). It is true also that the generation of alcohol in the liquor during fermentation, and the protracted way in which this is carried out in some varieties of ale breweries, would, in the first instance, cause the precipitation of the albumen and mucilage; but portions might still remain, and though the quantity might be apparently insignificant, yet under the various effects of temperature and other causes it would prove destructive, if not removed either during the fermentation in the shape of yeast, or before fermentation by boiling; or altogether excluded by a better system of mashing.

It is well known among brewers, if not in theory at least in effect, that beers retaining much nitrogenous substances, however richly they may be hopped and otherwise carefully prepared, cannot be preserved

in warm climates; neither will they retain their qualities at home when, on tapping, the air gets access to them, unless the temperature of the atmosphere be about 45° Fahr. (7°·2 C.), or lower; for as soon as the air is admitted, if the temperature is above 60° or 70° Fahr. (15°·5 to 21°·1 C.), the oxidation of the gluten commences, and the heat rises in consequence; the reaction set up causes the formation of a further quantity of alcohol from the sugar, and changes the alcohol already formed into acetic acid.

Were the fermentation of the worts carried on at a low temperature, as in Bavaria, then the excess of the albuminous and other analogous bodies might be allowed to remain without the least fear of their causing putrefaction and subsequent acetification, and there would be no need of removing any portion of them by the preparatory operation of boiling.

Many brewers allege that their only reason for boiling is the extraction of the lupulin of the hop, and to effect this the ebullition is continued at no small expense and trouble for a considerable period. Others, on the contrary, denounce boiling as being, next to acetic acid, the bane of the brewery; but reason affirms, and time and experience attest, that there is a mean which affords security from the bad effects of either extreme.

Vegetable albumen is insoluble in water at a temperature approaching ebullition, and the expansion of the air caused by the imbibition of the heat dissipates it as soon as it reaches 212° Fahr. (100° C.); the further continuation of the heat after this point is gained must evidently have in view the agglutination of the finely-divided insoluble particles already precipitated; but to prolong it more than fifteen minutes seems unreasonable, and is certainly prejudicial, inasmuch as portions of the saccharine matter will be decomposed, as before stated. The criterion which appears to regulate the time of the boiling in breweries is the formation of a mass of insoluble or precipitated matter. In place of this, the great object should be the coagulation of the particles, and their falling to the bottom in the copper should be less regarded; for during the fermentation, whilst the yet soluble portion of gluten is becoming insoluble by feeding the yeast, these will be carried away mechanically in the eviscerated matter, or deposited during the cleansing, without proving injurious to the liquor.

From these considerations it follows that the worts should not be subjected to a protracted ebullition, with the view of removing the albuminous ingredient, it being sufficient merely to render it insoluble; and whether it remains in the copper, is retained in the hop-back, or passes along to the fermenting tun to be there finally and entirely removed with the barm, is a matter of no very great moment, since it is deprived of the possibility of decomposing by oxidation within this period.

It will be observed from the description already given of the hop, that its efficacy as to flavour and bitterness depends upon the volatile aromatic oil and the resin which it contains; it likewise communicates astringency in consequence of the tannic acid or tannin which it yields. The gum and other matters removed from the flowers by water are of no very great interest.

If hops be macerated with water and subjected to distillation, the whole, or chief portion, of the oil will very readily pass over into the receiver, leaving the solution in the retort almost entirely destitute of smell, but retaining the bitterness and astringency of taste in a very marked degree. This is well known to brewers generally; and those who show some regard to facts, curtail in practice the time of boiling, or make such deviations from the old-established routine as seem to them best adapted for the retention of the aroma.

Were the "condition" or valuable portion of the hop extracted in such a way as to retain the volatile aromatic oil, there is no doubt the beer would be greatly improved in quality. Tizard made an effort in this direction by introducing his "hop-converter," by the use of which, he says, the most agreeable constituents are abstracted for the better kinds of ale, and if it be deemed necessary the coarser portions may be used up in the inferior products. His method of doing this is by converting the lower part of the under-back into a hop-back, by inserting a perforated floor above the true bottom of the mash-tun. Upon the solid bottom of this new hop-back, or above it, but beneath the perforated plates, coils of tubing are laid, through which steam from an adjacent boiler is forced, and for facility of management there should be a steam-cock fixed in the entrance pipe to regulate the flow of vapour. The hops, after being thoroughly broken up, are laid evenly upon the perforated floor of the hop-converter, four hours before setting the tap, and as much hot water poured upon them from the heated liquor-back as will effect their saturation completely; they are then left to digest for one hour, after which the steam is passed through the convoluted pipe till the mixture has attained a temperature of 200° Fahr. (93°·3 C.), retaining it at this point for the remainder of the time till the setting of the tap. The steam is then turned off, and the wort let in upon the hops to the depth of 6 inches, when the pump is worked, and the goods discharged upon the coolers, taking the precaution to preserve the depth of 6 inches of liquor upon the hops during the time of racking and sparging. In this way, Tizard asserts, the value of the hop is retained; for the temperature during the digestion being 12° Fahr. (5°·5 C.) below the boiling point, very little vapour is expelled; but it serves to withdraw the whole of the valuable constituents, and the worts being in contact with the hops during the exhaustion of the grist with the hot liquor—all the taps being open—the whole of their extract and essence is carried off in the goods.

In operating thus, it will be seen that Tizard discards boiling the worts, but this is in some measure compensated for by raising the heat of the mash towards the time of drawing off the wort to a temperature of 200° Fahr. (93°·3 C.), or upwards, by means of an attemperator, for the purpose of coagulating the albumen, and maintaining this degree for twenty

minutes or half an hour, as may seem best. Were the whole of the starch already converted into sugar, there is little doubt but that the method of steam boiling would be most suitable and economical. Steam boiling also supplants the several costly requisites which enter into the brewer's stock of apparatus and material, and thus effects a saving in the plant, while the work performed is, by proper management, as effectual and more satisfactory than when accomplished by the various coppers and furnaces.

Other contrivances have of late been resorted to for dispensing with boiling the worts and hops together, to obviate the danger of losing the aromatic constituents. Among these the process of NEWTON, of London, may be instanced, in which an extract of hops is prepared, which is then sold to the brewer.

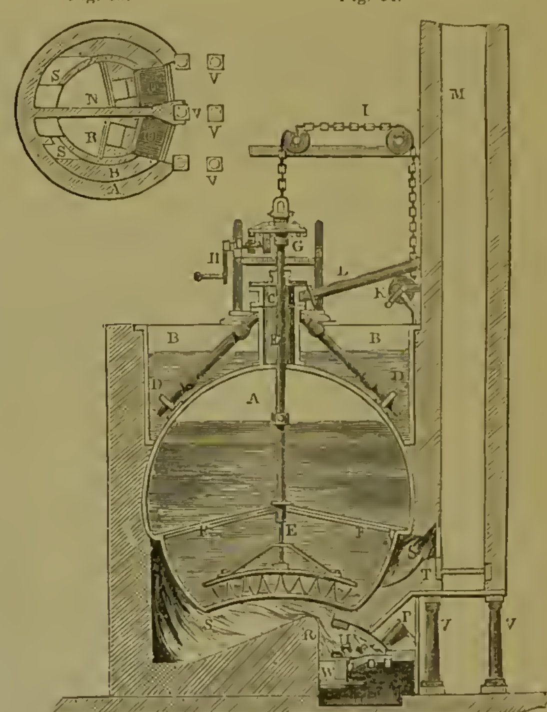
The same method has been followed for some time in France and some parts of the Continent, but the brewers in the United Kingdom do not appear to appreciate it. NEWTON'S mode of preparing the extract is as follows:—After having dried the hops at a low heat till they become so brittle as to be easily pulverized, the powder is passed through a coarse sieve for the purpose of retaining any stalks or pieces of wood which might be accidentally present; it is then put into a close vessel, and strong spirit of wine or alcohol poured over it till the whole becomes charged; this mixture is allowed to repose for twenty-four hours, after which the alcoholic tincture is drawn off into an appropriate receiver, and the residual powder washed as long as any extract is obtained.

The next course is to distil off the alcohol, by which means the oil and resinous body are left, mixed with a little water, which is also dispersed, first on the sand-bath and finally on the water-bath. The aqueous washings of the powdered leaves, which contain almost the whole of the resin, are also evaporated till the water is expelled; and when this is accomplished, and while the resinous matter is still warm, the oily body procured from the alcoholic tincture is added, and intimately mixed with it. One pound of this extract is said to be as efficacious as 3 lbs. of flowers.

Boiling Coppers.—The "liquor" for mashing has to be heated, and the wort has to be boiled; and although the mode of heating the liquor should properly be described before mashing, yet heating the liquor and boiling the wort being frequently done in the same manner, both are treated under the same heading. The usual temperature for heating is about 170° Fahr. (76°·6 C.), but the liquor is generally allowed to cool down to the required temperature. Formerly both liquor and wort were boiled in a brewing copper placed over a fire, but of late years steam has been largely used, especially for heating liquor. The following are the various modes of heating liquor now generally used.

Figs. 14 and 15 represent the old form of copper most usually erected in breweries; the former being an elevated section, and the latter a ground plan, of the fire and flue. In Fig. 14, A is the boiler or copper, hermetically sealed at the top, and convex at the bottom. Upon the top of this boiler is mounted a pan, B, containing water, which is heated by the steam arising from the boiling of the wort. A wide tube, C, rises from the uppermost part of the boiler, by which the steam generated during the ebullition of the liquor ascends, and is forced out by four tubes, two of which are seen at D D, into the liquor in the pan, B; the excess of vapour being carried off by the pipe, L, into the chimney, M. An iron shaft, E, passes down through a stuffing-box in the pipe, C, to the bottom of the vessel; at the lower end it is furnished with cross arms, from which chains are suspended, so as to sweep round the vessel. This mechanism is called "the rouser," and its object is to prevent the sediment

Fig. 15. Fig. 14.



which separates during the boiling from adhering to the bottom of the copper and getting charred. It is worked by a cogged wheel on the axis of the winch, H, gearing into the wheel, G. In order to remove the weight of the shaft off the wheel, it is partly supported at the bottom by a collar of metal borne by three stays, F F. It may be lifted by a chain, I, attached to its upper end, and, passing over the pulleys, is wound round the roller, K.

This vessel, when unusually large, is heated by two fires, separated by a wall, N—Fig. 15; O O are the grates on which the fire rests, and these are supplied by short slanting iron hoppers—seen in Fig. 14—which are kept constantly full of coals. Above these hoppers is formed a narrow aperture, for the admission of air in such proportion as is sufficient to insure the complete combustion of the smoke. A

bridge, R, at the back of each fire directs the flame upwards, so as to act upon the bottom of the copper, after which the heated vapours are conducted in semicircular flues, S S, round its sides, and finally enter the chimney, M, on the lower part of which a sliding damper plate, T, is placed for tempering the draught. When cold air is admitted at this orifice, the combustion of the fuel is immediately checked. Besides this, there is another slide plate at the entrance of the slanting flue into the chimney, for regulating the play of the flame under and round the boiler. If the plate, T, be opened, and the other one shut, the power of the fire is suspended. The arch of brickwork, U, over the fire, is intended to protect the front edge of the copper from the direct action of the flame. V V are the pillars on which the chimney is supported, and W is the opening through which the cinders and the ashes are drawn away.

Sometimes, instead of the steam having free exit through the pipes, D D, a weighted metallic valve, opening outward, is so arranged that no steam can escape until the liquor has reached some degrees beyond 212° Fahr., when its pressure becomes too powerful to be restrained by the weight of the valve. It then escapes, and the few degrees of extra heat which had combined with the liquid during the formation of this pressure-steam, is carried off in that which passes away, and the heat of the remainder immediately falls to 212° Fahr., when the valve closes the orifice tightly, till there is a further quantity formed which forces it open as before. In this manner the boiling is continued during the allotted time; but, instead of permitting the escape of the steam, it is conducted into water, as in the preceding figure, as well for heating the liquor as for retaining any part of the aroma which may be carried away by the vapour. This water is employed in subsequent mashings. Coppers of this form are now rarely made. A copper heated by a fire beneath it is still sometimes used. It frequently has a dome with an escape pipe in the centre, to prevent the steam from spreading about the brewery.

The capacity of the hot liquor copper should be about three barrels per quarter.

Another mode of heating liquor frequently adopted is by means of a wooden tub with a copper steam coil in it.

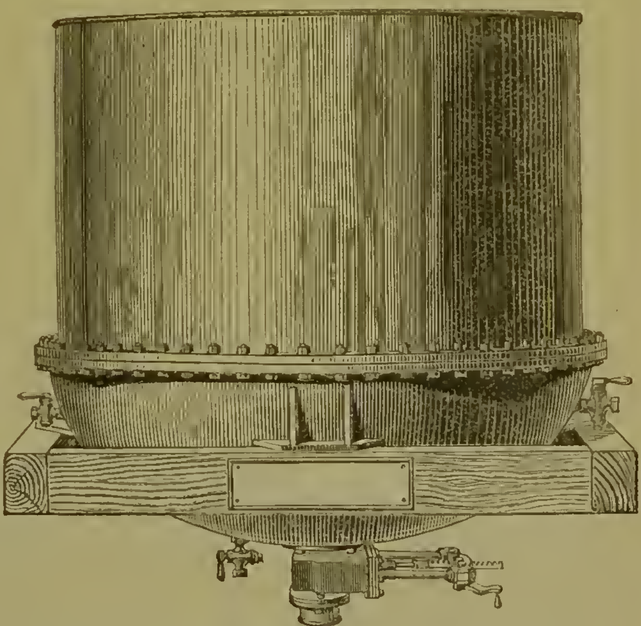
Occasionally steam is blown direct into the liquor, but this plan is not recommended, as it sometimes affects the quality of the liquor, and also makes a great deal of noise by the rapid condensation of the steam on coming in contact with the cold water.

Within the last few years a light copper vessel has been used instead of the wooden tub. Its first cost is greater, but it is cheapest in the end, owing to its superior durability, as the wooden tub will only last a few years. This copper has a steam coil like the wooden tub. There is no loss of heat by having a continuous worm for the steam, if the exit be so regulated that nothing but condensed water escapes, since this may be utilized by running it into a scalding copper for washing casks, &c.

The wort is boiled by several different means, and it is still an open question as to whether it is better to effect it by direct fire or by steam. Brewers differ considerably on this point, but the latter method is daily getting more into favour. Where fire is used a copper is employed, generally open at the top.

In boiling the wort by steam, a wooden tub and coil, or a copper vessel and coil, similar to those described for the hot liquor, may be used; but there is an objection to both, owing to the difficulty of removing the spent hops from between the tubes of the steam coil. This to some extent has been obviated by putting in a false bottom of iron, gun metal, or copper, similar to that already described for the mash-tun, so as to keep the hops from the steam coil, but the boiling is then not so satisfactory as with the fire copper.

Fig. 16.



The hops are run out through the discharge pipe with the wort, and then thrown up again from the hop back for the second wort. If the wooden tub or copper vessel be provided with a false bottom, the hops remain in, ready for the second boiling.

Undoubtedly the best method of boiling by steam is by means of the steam jacketed copper (Fig. 16). This consists of a hemispherical pan of copper, made entirely in one piece, with a cast or wrought iron jacket outside it, a space of from 2 to 3 inches being left between the two, the steam space being made tight by a flanged joint at the brims of the copper and iron pans. Above the pans, copper is continued to the required height for the capacity, this portion of the copper being comparatively thin, having to bear no pressure; but the copper pan and iron jacket

must be of sufficient substance to withstand a steam pressure of usually about 30 lbs. on the square inch. The jacket into which the steam is admitted is provided with a cock for the escape of the condensed water, and also with a cock in its upper part for the escape of the heated air on commencing operations. Unless this is carefully attended to an explosion is exceedingly likely to take place, from the great expansive force exerted by air suddenly heated.

The wort is discharged through the centre of the bottom, the pipe passing through the steam space between the copper and the jacket. Inside the copper, over the discharge outlet, is placed, when desired, a large copper perforated strainer, to keep the hops back for the second boiling. When the hops are retained in the wort-boiling vessel a hop back is not required.

The capacity of the wort copper should be about three barrels per quarter, which leaves sufficient space for boiling. Its position, where the wort is not pumped, should be such that it is commanded by the under-back into which the wort runs; but where the wort is pumped, it is generally placed sufficiently high in the brewery to command the hop back, coolers, &c.

Large wort coppers are generally fitted with a "rouser," for the purpose of keeping the wort and hops agitated, and to prevent the hops from settling on the bottom of the copper and burning. The rouser is made of iron; it has a vertical shaft placed in the centre of the copper, which is driven by steam power. On the bottom of the vertical shaft is a horizontal one, reaching from side to side of the copper, on which are hung iron chains in festoons, the chains dragging on the bottom of the copper. (See Fig. 14.)

When the boiling is completed, the discharge cock of the copper is opened, and the whole contents run into the hop back. The hop back is generally of a rectangular form, from 3 to 5 feet deep, made of wood, iron, or copper, and fitted with a false bottom, similar to that of the mash-tun. Many brewers who do not object to the iron false bottom in the mash-tun, object to it in the hop back, as they consider that iron has a more detrimental effect upon the wort after it has been boiled than before.

When the wort has remained in the hop back a sufficient time to settle, it is drawn off into the cooler, leaving the hops behind; and the hops, when thoroughly strained, are carried off into the hop copper, ready for the second boiling. This is done by hand in small breweries, but in large ones it is usual to employ an elevator very similar in construction to that used for elevating grist or malt. When the hops come out of the wort copper with the second boiling, and have been strained in the hop back as they were from the first wort, they are counted as refuse, and are frequently burned in the copper furnace. In many cases the spent hops are pressed, in order to extract from them the beer that has not strained off in the hop back, an ordinary screw press being used; but in some instances hydraulic presses, specially constructed, have been used with advantage.

Opinions differ as to the advantage of pressing hops, as some brewers contend that the beer so obtained is inferior in quality, having in it a coarse bitter of the hops which is not liked, especially in beers of the finest quality.

The criterion by which practical brewers judge of the completion of the work is the "breaking," or the formation of numerous flocks of coagulated matter.

Ordinary ales, when the grist is exhausted in two or three mashings, are ordinarily boiled thus—

First wort,....................	1 hour.
Second "	2 hours.

When there are three worts the boiling is, for the

First wort,....................	1 hour.
Second "	1½ hour.
Third "	2 hours.

In these cases the first extract is boiled forty minutes before the hops are added, and fifteen minutes after; the gyle is then racked off, and the second worts are pumped into the copper and treated as specified above.

When the ale is to be stored the practice is to add the hops and continue the ebullition till the coagulated matter agglutinates and falls to the bottom, after which the whole contents of the boiler are discharged to the store cask, which, when full, is tightly bunged, and then permitted to remain till the fermentation and settling are both finished. Considerable time is required in this instance, often extending to twelve, eighteen, and even twenty-four months. Instead of putting the hops into the boiler with the wort, some persons pick or rub them between the hands, and when they are completely loosened, strew them on the bottom of the store cask, and run in the hot wort upon them after three-quarters of an hour's boil; when the cask is full it is bunged, as in the preceding instance, and, if considered necessary, a safety-valve is attached. The fermentation and cleansing take place as before. Where the object is to procure a highly-flavoured aromatic ale, this practice is no doubt successful, especially when the hops are used in larger quantities than in ordinary cases; but in commercial establishments this plan is now never adopted, though at one time it was much followed. Another custom is to macerate about a fourth of the hops with the worts, and boil—the remainder being reserved in the tun to be digested with the goods during the time allotted for the slow progressive fermentation, &c.

The trading brewers, in many cases, vary their operations, apparently with no great advantage; but the following seems to be their usual routine:—Whilst the wort is being pumped into the copper the hops are weighed out, according to the allowance per quarter, picked, and thrown on the surface of the liquor, when the boiling is performed in the open pan, but macerated with it when the closed copper is used. The layer of hops excludes contact

with tho air to some extent till the wort rises to ebullition, and thus any injury which might arise by spontaneous decomposition, till the temperature of the liquor reaches to 212° Fahr. (100° C.), is avoided. The steam is allowed to permeate the hops to open their pores, for the abstraction of their bitter and other constituents, for some time before they are beaten into the wort; and the boiling is continued till the formation of the flocks, or for a specified time, say one, two, or in case of stock ales which are exported, for three hours. In addition to the vegetable albumen which separates from the worts by mere boiling, the tannin of the hop unites with a further quantity and precipitates it, leaving the liquor comparatively pure, and impregnated with the preservative bitter of the hop flower.

The quantity of hops added to the worts is dependent upon the quality of the product and the strength of the worts, and also upon the length of time they are to be retained, or the climate they have to endure. The quality of the flowers has also an influence upon the proportion required to communicate the requisite properties to the liquor. For this reason the ales prepared for the export trade, such as East India pale ales, &c., are always more richly hopped than those to be used at home.

The allowance of hops per quarter of malt will be found in the annexed table by LEVESQUE; it extends from one-eighth of a pound to 14 lbs. per quarter. Some of the fine ales, made to keep good in hot climates, have a quantity of hops added to them much larger than that which is here mentioned, amounting indeed sometimes to 18 or 22 lbs. per quarter of malt, whereas the proportion allotted to common ales is not more than from 6 to 8 lbs., and very rarely 10 lbs. For inferior ales 4 lbs. of hops per quarter of malt is sometimes thought to be sufficient.

If the produce of the malt be obtained in two or more mashings, and these are boiled separately, the proportion of hops which each wort will require is found as follows:—Suppose the quantity taken was 80 qrs. of malt, and that the gravity per quarter is 85 lbs., the whole being extracted in two mashes, the first of which tests 65 lbs., and the other, together with the washings, 20 lbs. per quarter. Further, if the proportion of hops to the quarter of 70 lbs. gravity be 12 lbs., by referring to the gravity, 85 lbs. in the table, the number 14·571 will be found on the horizontal line under the head of 12 lbs. per quarter. Then $85 \times 14{\cdot}571 = 1238{\cdot}5$ lbs. of hops, and $80 \times 85 = 6800$ lbs., the total extract; and $6800 = 1238{\cdot}5 = 0{\cdot}1821$ lbs. of hops for each pound gravity in each of the worts; and hence $65 \times 80 \times 0{\cdot}182 = 946{\cdot}9$ lbs for the first wort, $20 \times 80 \times 0{\cdot}182 = 291{\cdot}6$ lbs. for the second wort.

In a similar way, the proportion of the flowers which ought to be added to the several liquors is found, at whatever number of pounds per quarter, as specified in the table, is adopted.

Sometimes the whole of the hops is added to the first wort; but the time of boiling is then shortened, so as to leave a sufficient amount of the bitter principle for the next liquor. The practice most frequently followed is to add the proper quantity to each wort and discharge the whole, when the usual time of boiling is expired, into the hop back. The ebullition in this case is continued for one half to three quarters of an hour longer in the second than in the first wort, to remove the excess of impurities which the after mashings generally carry along with them, and to exhaust the hops as well as to concentrate the gyle, and procure a better quality of ale than they would afford in their diluted state.

The brewer, however, applies here only an imperfect remedy for the self-inflicted evil of drawing off repeated mashings in a very diluted state, for by such a course of ebullition the sugar is partly decomposed, as already explained, the wort deepens in colour, and the expenditure in fuel becomes a dead loss. After the boiling, the gyle and hops are drawn off to the hop back, and the liquor is made to percolate through the hops used in the foregoing operation. Any strong wort which might be retained in the exhausted hops is carried off in the second gyle, and what is retained of the second is washed off with hot water, and the washings preserved for a return wort; or in case light ales are to be made, added to the product in the cooler; or the residuary fibrous matter of the hops is removed to the press, and the liquor squeezed out in this way added to the second gyle.

A larger quantity of hops is always used in hot weather then when the air is cold or mild, in order to prevent the decomposition of the ale, which, without this counteracting agent, the elevated temperature would occasion.

The following are LEVESQUE'S tables. The first shows the increase of hops required for every degree from 50° to 75° Fahr. (10° to 23°·8 C.), and from 4 to 9 lbs. per quarter:—

Temperature of the air at the time of brewing.		Four pounds per quarter.	Five pounds per quarter.	Six pounds per quarter.	Seven pounds per quarter.	Eight pounds per quarter.	Nine pounds per quarter.
Fahr.	C.						
50°	10°	4·00	5·00	6·00	7·00	8·00	9·00
51	10·5	4·08	5 10	6·12	7·14	8·16	9·18
52	11·1	4·16	5·20	6·24	7·28	8·32	9·36
53	11·6	4·24	5·30	6·36	7·42	8·48	9·54
54	12·2	4·32	5·40	6·48	7·56	8·64	9·72
55	12·7	4·40	5·50	6·60	7·70	8·80	9·90
56	13·3	4·48	5·60	6·72	7·84	8·96	10 08
57	13·8	4·56	5·70	6·84	7·98	9·12	10·26
58	14·4	4·64	5·80	6·96	8·12	9·28	10·44
59	15·0	4·72	5·90	7·08	8·26	9·44	10·52
60	15·5	4·80	6·00	7·20	8·40	9·60	10·70
61	16·1	4·88	6·10	7·32	8·54	9·76	10·88
62	16·6	4·96	6·20	7·44	8·68	9·92	11·06
63	17·2	5·04	6·30	7·56	8·82	10·08	11·24
64	17·7	5·12	6·40	7·68	8·96	10·24	11·42
65	18·3	5·20	6·50	7·80	9·10	10·40	11·60
66	18·8	5·28	6·60	7·92	9·24	10 56	11·88
67	19·4	5·36	6·70	8·04	9·38	10·72	12·06
68	20·0	5·44	6·80	8·16	9·52	10·88	12·24
69	20·5	5·52	6·90	8·28	9·66	11·04	12·42
70	21·1	5·60	7·00	8·40	9·80	11·20	12·60
71	21·6	5·68	7·10	8·52	9·94	11·36	12·78
72	22·2	5·76	7·20	8·64	10·08	11·52	12·96
73	22·7	5·84	7·30	8·76	10·22	11·68	13·14
74	23·3	5·92	7·40	8·88	10·36	11·84	13·32
75	23·8	6·00	7·50	9·00	10·50	12·00	13·50

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 pounds per quarter.

Gravity.	⅛	¼	½	¾	1	1¼	1½	1¾	2	2¼	2½	2¾
70	0·1250	0·2500	0·5000	0·7500	1·0000	1·2500	1·5000	1·7500	2·0000	2·2500	2·5000	2·7500
71	0·1267	0·2535	0·5070	0·7607	1·0142	1·2678	1·5214	1·7750	2·0285	2·2821	2·5861	2·7892
72	0·1281	0·2570	0·5140	0·7714	1·0284	1·2856	1·5128	1·8000	2·0570	2·3142	2·6228	2·8284
73	0·1301	0·2605	0·5210	0·7821	1·0426	1·3034	1·5642	1·8250	2·0855	2·3463	2·6592	2·8676
74	0·1318	0·2640	0·5280	0·7928	1·0568	1·3212	1·5856	1·8500	2·1140	2·3784	2·6956	2·9068
75	0·1335	0·2675	0·5350	0·8035	1·0710	1·3390	1·6070	1·8750	2·1425	2·4105	2·7320	2·9460
76	0·1352	0·2710	0·5120	0·8142	1·0852	1·3568	1·6284	1·9000	2·1710	2·4426	2·7681	2·9852
77	0·1369	0·2745	0·5490	0·8249	1·0994	1·3746	1·6198	1·9250	2·1995	2·4717	2·8048	3·0244
78	0·1386	0·2780	0·5560	0·8356	1·1136	1·3924	1·6712	1·9500	2·2280	2·5068	2·8412	3·0636
79	0·1403	0·2815	0·5630	0·8463	1·1278	1·4102	1·6920	1·9750	2·2565	2·5389	2·8776	3·1028
80	0·1420	0·2850	0·5700	0·8570	1·1420	1·4280	1·7140	2·0000	2·2850	2·5710	2·9140	3·1420
81	0·1437	0·2885	0·5770	0·8677	1·1562	1·4158	1·7354	2·0250	2·3135	2·6031	2·9501	3·1812
82	0·1454	0·2920	0·5840	0·8784	1·1704	1·4636	1·7568	2·0500	2·3420	2 6352	2·9868	3·2204
83	0·1171	0·2955	0·5910	0·8891	1·1846	1·4814	1·7782	2·0750	2·3705	2·6673	3·0232	3 2596
84	0·1488	0·2990	0·5980	0·8998	1·1988	1·5092	1·7996	2·1000	2·3990	2·6994	3·0596	3·2988
85	0·1505	0·3025	0·6050	0·9105	1·2130	1·5260	1·8210	2·1250	2·4275	2·7315	3·0960	3·3380
86	0·1522	0·3060	0·6120	0·9212	1·2272	1·5438	1·8424	2·1500	2·1560	2·7636	3·1321	3·3772
87	0·1539	0·3095	0·6190	0·9319	1·2414	1·5616	1·8638	2·1750	2·4845	2·7957	3·1688	3·4164
88	0·1556	0·3130	0·6260	0·9426	1·2556	1·5794	1·8852	2·2000	2·5130	2·8278	3·2052	3·4556
89	0·1573	0·3165	0·6330	0·9533	1·2698	1·5972	1·9066	2·2250	2·5415	2·8599	3·2116	3·4948
90	0·1590	0·3200	0·6400	0·9640	1·2840	1·6050	1·9280	2·2500	2·5700	2·8920	3·2780	3·5340
91	0·1607	0·3235	0·6470	0·9747	1·2982	1·6228	1·9494	2·2750	2·5985	2·9240	3·3141	3·5732
92	0·1624	0.3270	0·6540	0·9854	1·3124	1·6406	1·9708	2·3000	2·6270	2·9562	3·3508	3·6124
93	0·1641	0·3305	0·6610	0 9961	1·3266	1·6584	1·9922	2·3250	2·6555	2·9883	3·3872	3·6156
94	0·1658	0·3340	0·6680	1·0068	1·3408	1·6762	2·0136	2·3500	2·6840	3·0204	3·4236	3·6908
95	0·1675	0·3375	0·6750	1·0175	1·3550	1·6940	2·0350	2·3750	2·7125	3·0525	3·4600	3·7300
96	0·1692	0·3110	0·6820	1·0282	1·3692	1·7118	2·0564	2·4000	2·7410	3·0846	3·1964	3·7692
97	0·1709	0·3445	0·6890	1·0389	1·3834	1·7296	2·0778	2·4250	2·7695	3·1167	3·5328	3·8084
98	0·1726	0·3480	0·6960	1·0496	1·3976	1·7474	2·0992	2·4500	2·7980	3·1488	3·5692	3·8476
99	0·1743	0·3515	0·7030	1·0603	1·4118	1·7652	2·1206	2·4750	2·8265	3·1809	3·6056	3·8868
100	0·1760	0·3550	0·7100	1·0710	1·1260	1·7830	2·1423	2·5000	2·8550	3·2130	3·6420	3·9260
101	0·1777	0·3580	0·7170	1·0817	1·4402	1·8008	2·1634	2·5250	2·8835	3·2451	3·6784	3·9652
102	0·1794	0·3620	0·7240	1·0924	1·4544	1·8186	2·1848	2·5500	2·9120	3·2772	3·7148	4·0044
103	0·1811	0·3655	0·7310	1·1031	1·4686	1·8364	2·2062	2·5750	2·9405	3·3093	3·7512	4·0436
104	0·1828	0·3698	0·7380	1·1008	1·4828	1·8542	2·2276	2·6000	2·9690	3·3414	3·7876	4·0828
105	0·1845	0·3725	0·7450	1·1245	1·4970	1·8720	2·2490	2·6250	2·9975	3·3735	3·8240	4·1220

TABLE continued.

Gravity.	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾
70	3·0000	3·2500	3·5000	3·7500	4·0000	4·2500	4·5000	4·7500	5·0000	5·2500	5·5000	5·7500
71	3·0428	3·2964	3·5500	3·8035	4·0571	4·3107	4·5642	4·8178	5·0714	5 3250	5·5785	5·8321
72	3·0856	3·3428	3·6000	3·8570	4·1142	4·3714	4·6284	4·8856	5·1428	5·4000	5·6570	5·9142
73	3·1284	3·3892	3·6500	3·9705	4·1713	4·4321	4·6926	4·9534	5·2142	5·4750	5·7355	5·9963
74	3 1712	3·4356	3·7000	3·9640	4·2284	4·4928	4·7568	5·0212	5·2856	5·5500	5·8140	6·0784
75	3·2140	3·4820	3·7500	4·0175	4·2855	4·5535	4·8210	5·0890	5·3570	5·6250	5·8925	6·1605
76	3·2568	3·5284	3·8000	4·0710	4·3426	4·6142	4·8852	5·1568	5·4284	5·7000	5·9710	6·2426
77	3·2996	3·5748	3·8500	4·1245	4·3994	4·6749	4·9494	5·2246	5·4998	5·7750	6·0495	6·3247
78	3·3424	3·6212	3·9000	4·1780	4·4568	4·7356	5·0136	5·2924	5·5712	5·8500	6·1280	6·4068
79	3·3852	3·6676	3·9500	4·2315	4·5139	4·7963	5·0778	5·3602	5·6426	5·9250	6·2065	6·4889
80	3·4280	3·7140	4·0000	4·2850	4·5710	4·8570	5·1420	5·4280	5·7140	6·0000	6·2850	6·5710
81	3·4708	3·7604	4·0500	4·3385	4·6281	4·9177	5·2062	5·4958	5·7854	6·0750	6·3635	6·6531
82	3·5136	3·8068	4·1000	4·3920	4·6852	4·9784	5·2704	5·5636	5·8568	6·1500	6·4420	6·7352
83	3·5564	3·8532	4·1500	4·4455	4·7423	5·0391	5·3346	5·6314	5·9282	6·2250	6·5205	6·8173
84	3·5992	3·8996	4·2000	4·4990	4·7994	5·0998	5·3998	5·6992	5·9996	6·3000	6·5990	6·8994
85	3·6420	3·9460	4·2500	4·5525	4·8565	5·1605	5·4630	5·7670	6·0710	6·3750	6·6775	6·9815
86	3·6848	3·9924	4·3000	4·6060	4·9136	5·2212	5·5272	5·8348	6·1424	6·4500	6·7560	7·0636
87	3·7276	4·0388	4·3500	4·6595	4·9707	5·2819	5·5914	5·9026	6·2138	6·5250	6·8345	7·1457
88	3·7704	4·0852	4·4000	4·7130	5·0278	5·3426	5·6556	5·9704	6·2852	6·6000	6·9130	7·2278
89	3·8132	4·1316	4·4500	4·7665	5·0849	5·4033	5·7198	6·0382	6·3566	6·6750	6·9915	7·3099
90	3·8560	4·1780	4·5000	4·8200	5·1420	5·4640	5·7840	6·1060	6·4280	6·7500	7·0700	7·3920
91	3·8988	4·2244	4·5500	4·8735	5·1991	5·5247	5·8482	6·1738	6·4994	6·8250	7·1485	7·1741
92	3·9416	4·2708	4·6000	4·9270	5·2562	5·5854	5·9124	6·2416	6·5708	6·9000	7·2270	7·5562
93	3·9844	4·3172	4·6500	4·9805	5·3133	5·6461	5·9766	6·3094	6·6422	6·9750	7·3055	7·6383
94	4·0272	4·3636	4·7000	5·0340	5·3704	5·7068	6·0408	6·3772	6·7136	7·0500	7·3840	7·7204
95	4·0700	4·4100	4·7500	5·0875	5·4275	5·7675	6·1050	6·4450	6·7850	7·1250	7·4625	7·8025
96	4·1128	4·4564	4·8000	5·1410	5·4846	5·8282	6·1692	6·5128	6·8564	7·2000	7·5410	7·8846
97	4·1556	4·5028	4·8500	5·1945	5·5417	5·8889	6·2334	6·5806	6·9278	7·2750	7·6195	7·9667
98	4·1984	4·5192	4·9000	5·2480	5·5988	5·9496	6·2976	6·6184	6·9992	7·3500	7·6980	8·0488
99	4·2412	4·5956	4·9500	5·3015	5·6559	6·0103	6·3618	6·7162	7·0706	7·4250	7·7765	8·1309
100	4·2840	4·6420	5·0000	5·3550	5·7130	6·0710	6·4260	6·7840	7·1420	7·5000	7·8550	8·2130
101	4·3268	4 6884	5·0500	5·4085	5·7701	6·1317	6·4902	6·8518	7·2134	7·5750	7·9335	8·2951
102	4·3696	4·7348	5·1000	5·1620	5·8272	6·1924	6·5544	6·9196	7·2848	7·6500	8·0120	8·3772
103	4·4124	4·7812	5·1500	5·5155	5·8843	6·2531	6·6186	6·9874	7·3562	7·7250	8·0905	8·4593
104	4·4552	4·8276	5·2000	5·5690	5·9414	6·3138	6·6828	7·0552	7·4276	7·8000	8·1690	8·5414
105	4·4980	4·8740	5·2500	5·6225	5·9985	6·3745	6·7470	7·1230	7·4990	7·8750	8·2475	8·6235

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 pounds per quarter.—Continued.

Gravity.	6	6¼	6½	6¾	7	7¼	7½	7¾	8	8¼	8½
70	6·0000	6·2500	6·5000	6·7500	7·0000	7·2500	7·5000	7·7500	8·0000	8·2500	8·5000
71	6·0857	6·3392	6·5928	6·8464	7·1000	7·3535	7·6071	7·8607	8·1142	8·3678	8·6214
72	6·1714	6·4284	6·6856	6·9428	7·2000	7·4570	7·7142	7·9714	8·2284	8·4856	8·7428
73	6·2571	6·5176	6·7784	7·0392	7·3000	7·5605	7·8213	8·0821	8·3426	8·6034	8·8642
74	6·3428	6·6068	6·8712	7·1356	7·4000	7·6640	7·9284	8·1928	8·4568	8·7212	8·9850
75	6·4285	6·6960	6·9640	7·2320	7·5000	7·7675	8·0355	8·3035	8·5710	8·8390	9·1070
76	6·5142	6·7852	7·0568	7·3284	7·6000	7·8710	8·1426	8·4142	8·6852	8·9568	9·2284
77	6·5999	6·8744	7·1496	7·4240	7·7000	7·9745	8·2497	8·5249	8·7994	9·0746	9·3498
78	6·6856	6·9636	7·2424	7·5212	7·8000	8·0780	8·3568	8·6356	8·9136	9·1924	9·4712
79	6·7713	7·0528	7·3352	7·6176	7·9000	8·1815	8·4639	8·7463	9·0278	9·3102	9·5927
80	6·8570	7·1420	7·4280	7·7140	8·0000	8·2850	8·5710	8·8570	9·1420	9·4280	9·7140
81	6·9427	7·2312	7·5208	7·8104	8·1000	8·3885	8·6781	8·9677	9·2562	9·5458	9·8354
82	7·0284	7·3204	7·6136	7·9068	8·2000	8·4920	8·7852	9·0784	9·3704	9·6636	9·9568
83	7·1141	7·4096	7·7064	8·0032	8·3000	8·5955	8·8923	9·1891	9·4846	9·7814	10·0782
84	7·1998	7·4988	7·7992	8·0996	8·4000	8·6996	8·9094	9·2998	9·5998	9·8992	10·1996
85	7·2855	7·5880	7·8920	8·1960	8·5000	8·8025	9·1065	9·4105	9·7130	10·0170	10·3210
86	.7·3712	7·6772	7·9848	8·2924	8·6000	8·9060	9·2136	9·5212	9·8272	10·1348	10·4424
87	7·4569	7·7664	8·0776	8·3888	8·7000	9·0005	9·3207	9.6319	9·9414	10·2526	10·5638
88	7·5426	7·8556	8·1704	8·4852	8·8000	9·1130	9·4278	9·7426	10·0516	10·3704	10·6852
89	7·6283	7·9448	8·2632	8·5816	8·9000	9·2165	9·5349	9·8533	10·1608	10·4882	10·8006
90	7·7140	8·0340	8·3560	8·6780	9·0000	9·3200	9·6420	9·9640	10·2840	10·6060	10·9280
91	7·7997	8·1232	8·4488	8·7744	9·1000	9·4235	9·7491	10·0747	10·3982	10·7238	11·0494
92	7·8854	8·2124	8·5416	8·8708	9·2000	9·5270	9·8562	10·1854	10·5124	10·8416	11·1708
93	7·9771	8·3016	8·6344	8·9672	9·3000	9·6305	9·9633	10·2961	10·6266	10·9514	11·2922
94	8·0568	8·3908	8·7272	9·0636	9·4000	9·7340	10·0704	10·4068	10·7408	11·0772	11·4136
95	8·1425	8·4800	8·8200	9·1600	9·5000	9·8375	10·1775	10·5175	10·8550	11 2950	11·5350
96	8·2282	8·5692	8·9128	9·2564	9·6000	9·9410	10·2846	10·6282	10·9692	11·3128	11·6564
97	8·3139	8·6584	9·0056	9·3528	9·7000	10·0445	10·3917	10·7389	11·0834	11·4306	11·7778
98	8·3996	8·7476	9·0984	9·4492	9·8000	10·1480	10·4988	10·8496	11·1976	11·5484	11·8992
99	8·4853	8·8368	9·1912	9·5456	9·9000	10·2515	10·6059	10·9603	11·3118	11·6662	12·0206
100	8·5710	8·9260	9·2840	9·6420	10·0000	10·3550	10·7130	11·0710	11·4260	11·7840	12·1420
101	8·6567	9·0152	9·3768	9·7384	10·1000	10·4585	10·8201	11·1817	11·5402	11·9018	12·2634
102	8·7424	9·1044	9·4696	9·8348	10·2000	10·5620	10·9272	11·2924	11·6544	12·0196	12·3848
103	8·8281	9·1936	9·5624	9·9312	10·3000	10·6655	11·0343	11·4031	11·7686	12·1374	12·5062
104	8·9138	9·2828	9·6552	10·0276	10·4000	10·7690	11·1414	11·5138	11·8828	12·2552	12·6267
105	8·9995	9·3720	9·7480	10·1240	10·5000	10·8725	11·2485	11·6245	11·9970	12·3730	12·7490

TABLE continued.

Gravity.	8¾	9	9¼	9½	9¾	10	10¼	10½	10¾	11	11¼
70	8·7500	9·0000	9·2500	9·5000	9·7500	10·0000	10·2500	10·5000	10·7500	11·0000	11·2500
71	8·8750	9·1285	9·3821	9·6357	9·8892	10·1428	10·3964	10·6500	10·9035	11·1571	11·4107
72	9·0000	9·2570	9·5142	9·7714	10·0284	10 2856	10·5428	10·8000	11·0570	11·3142	11·5714
73	9·1250	9·3855	9·6463	9·9071	10·1676	10·4284	10·6892	10·9500	11·2105	11·4713	11·7321
74	0·2500	9·1140	9·7784	10·0428	10·3068	10·5712	10·8356	11·1000	11·3640	11·6284	11·8928
75	9·3750	9·6465	9·9105	10·1785	10·4460	10·7140	10·9820	11·2500	11·5175	11·7855	12·0535
76	9·5000	9·7710	10·0426	10·3142	10·5852	10·8568	11·1284	11·4000	11·6710	11·9426	12·2142
77	9·6250	9·8995	10·1747	10·4499	10·7244	10·9996	11·2748	11·5500	11·8245	12·0997	12·3749
78	9·7500	10·0280	10·2068	10·5856	10·8636	11·1424	11·4212	11·7000	11·9780	12·2568	12·5356
79	9·8750	10·1565	10·4389	10·7213	11·0028	11·2852	11·5676	11·8500	12·1315	12·4139	12·6963
80	10·0000	10·2850	10·5710	10·8570	11·1420	11·4280	11·7140	12·0000	12·2850	12·5710	12·8570
81	10·1250	10 4135	10·7031	10·9927	11·2812	11·5708	11·8604	12·1500	12·4385	12·7281	13·0177
82	10·2500	10·5420	10·8352	11·1284	11·4204	11·7136	12·0068	12·3000	12·5920	12·8852	13·1784
83	10·3750	10·6705	10·9673	11·2641	11·5296	11·8564	12·1532	12·4500	12·7455	13·0423	13·3391
84	10·5000	10·7990	11·0994	11·3998	11·6988	11·9992	12·2996	12·6000	12·8990	13·1994	13·4998
85	10·6250	10·9275	11·2315	11·5355	11·8380	12·1420	12·4460	12·7500	13·0525	13·3565	13·6605
86	10·7500	11·0560	11·3636	11·6712	11·9772	12·2848	12·5924	12·9000	13·2060	13·5136	13·8212
87	10·8750	11·1845	11·4957	11·8069	12·1164	12·4276	12·7388	13·0500	13·3595	13·6707	13·9819
88	11·0000	11·3130	11·6278	11·9426	12·2556	12·5704	12·8852	13·2000	13·5130	13·8278	14·1426
89	11·1250	11·4415	11·7599	12·0783	12·3948	12·7132	13·0316	13·3500	13·6665	13·9849	14·3033
90	11·2500	11·5700	11·8920	12·2140	12·5340	12·8560	13·1780	13·5000	13·8200	14·1420	14·4640
91	11·3750	11·6985	12·0241	12·3497	12·6732	12·9988	13·3244	13·6500	13·9735	14·2991	14·6247
92	11·5000	11·8270	12·1562	12·4854	12·8124	13·1416	13·4708	13·8000	14·1270	14·4562	14·7854
93	11·6250	11·9555	12·2883	12·6211	12·9516	13·2844	13·6172	13·9500	14·2805	14·6133	14·9461
94	11·7500	12·0840	12·4204	12·7568	13·0908	13·4272	13·7636	14·1000	14·4340	14·7704	15·1068
95	11·8750	12·2125	12·5525	12·8925	13·2300	13·5700	13·9100	14·2500	14 5875	14·9275	15·2675
96	12·0000	12·4410	12·6846	13·0282	13·3692	13·7128	14·0564	14·4000	14·7410	15·0846	15·4282
97	12·1250	12·5695	12·8167	13·1639	13·5084	13·8556	14·2028	14·5500	14·8945	15·2417	15·5899
98	12·2500	12·6980	12·9488	13·2996	13·6476	13·9984	14·3492	14·7000	15·0480	15·3988	15·7496
99	12·3750	12·8265	13·0809	13·4353	13·7868	14·1412	14·4496	14·8500	15·2015	15·5559	15·9103
100	12·5000	12·9550	13·2130	13·5710	13·9260	14·2840	14·6420	15·0000	15·3550	15·7130	16·0710
101	12·6250	13·0835	13·3451	13·7067	14·0652	14·4268	14·7884	15·1500	15·5085	15·8701	16·2317
102	12·7500	13·2120	13·4772	13·8424	14·2044	14·5696	14·9348	15·3000	15·6620	16·0272	16·3924
103	12·8750	13·3405	13·5093	13·9781	14·3436	14·7124	15·0812	15·4500	15·8155	16·1843	16·5531
104	13·0000	13·4680	13·7414	14·1138	14·4828	14·8552	15·2276	15·6000	15·9690	16·3414	16·7138
105	13·1250	13·5965	13·8735	14·2495	14·6220	14·9980	15·3740	15·7500	16·1225	16·4985	16·8745

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 lbs. per quarter.—Concluded.

Gravity.	11½	11¾	12	12¼	12½	12¾	13	13¼	13½	13¾	14
70	11·5000	11·7500	12·0000	12·2500	12·5000	12·7500	13·0000	13·2500	13·5000	13·7500	14·0000
71	11·6612	11·9178	12·1714	12·4250	12·6785	12·9321	13·1857	13·4392	13·6928	13·9464	14·2000
72	11·8284	12·0856	12·3428	12·6000	12·8570	13·1142	13·3714	13·6284	13·8865	14·1428	14·4000
73	11·9926	12·2534	12·5112	12·7750	13·0320	13·2963	13·5571	13·8176	14·0784	14·3392	14·6000
74	12·1568	12·1212	12·6856	12·9500	13·2105	12·4784	13.7428	14·0068	14·2712	14·5356	14·8000
75	12·3210	12·5890	12·8570	13·1250	13·3890	13·6605	13·9285	14·1960	14·4610	14·7320	15·0000
76	12·4852	12·7568	13·0284	13·3000	13·5675	13·8426	14·1142	14·3852	14·6568	14·9284	15·2000
77	12·6494	12·9246	13·1998	13·4750	13·7460	14·0247	14·2999	14·5744	14·8496	15·1248	15·4000
78	12·8136	13·0924	13·3712	13·6500	13·9245	14·2068	14·4856	14·7636	15·0424	15·3212	15·6000
79	12·9778	13·2602	13·5426	13·8250	14·1030	14·3889	14·6713	14·9528	15·2352	15·5176	15·8000
80	13·1420	13·4280	13·7140	14·0000	14·2815	14·5710	14·8570	15 1410	15·4280	15·7140	16·0000
81	13·3062	13·5958	13·8885	14·1750	14·4600	14·7531	15·0427	15·3302	15·6208	15·9401	16·2000
82	13·4704	13·7636	14·0568	14·3500	14·6385	14·9352	15·2284	15·5194	15·8136	16·1068	16·4000
83	13·6346	13·9314	14·2282	14·5250	14·8170	15·1173	15·4141	15·7086	16·0064	16·3032	16·6000
84	13·7988	14·0992	14·3996	14·7000	14·9955	15·2994	15·5998	15·8978	16·1992	16·4996	16·8000
85	13·9630	14·2670	14·5710	14·8750	15·1740	15·4815	15·7855	16·0870	16·3920	16·6960	17·0000
86	14·1272	14·4348	14.7424	15·0500	15·3525	15·6636	15·9712	16·2762	16·5848	16·8924	17·2000
87	14·2914	14·6026	14·9138	15·2250	15·5310	15·8457	16·1569	16·4654	16·7776	17·0888	17·4000
88	14·4556	14·7740	15·0852	15·4000	15·7095	16·0278	16·3426	16·6546	16·9704	17·2852	17·6000
89	14·6198	14·9382	15·2566	15·5750	15·8880	16·2099	16·5283	16·8438	17·1632	17·4816	17·8000
90	14·7840	15·1060	15·4280	15·7500	16·0665	16·3920	16·7146	17·0320	17·3560	17·6780	18·0000
91	14·9482	15·2738	15·5994	15·9250	16·2450	16·5741	16·8997	17·2212	17·5488	17·8744	18·2000
92	15·1124	15·4416	15·7708	16·1000	16·4235	16·7562	17·0854	17·4104	17·7416	18·0708	18·4000
93	15·2766	15·6694	15·9422	16·2750	16·6020	16·9383	17·2711	17·6096	17·9344	18·2672	18·6000
94	15·4408	15·7772	16·1136	16·4500	16·7805	17·1204	17·4568	17·7988	18·1272	18·4636	18·8000
95	15·6050	15·9450	16·2850	16·6250	16·9590	17·3025	17·6425	17·9880	18·3200	18·6600	19·0000
96	15·7692	16·1128	16·4564	16·8000	17·1375	17·4846	17·8282	18·1772	18·5128	18·8564	19·2000
97	15·9331	16·2806	16·6278	16·9750	17·3160	17·6667	18·0139	18·3664	18·7056	19·0528	19·4000
98	16·0976	16·4484	16·7992	17·1500	17·4945	17·8488	18·1996	18·5556	18·8984	19·2492	19·6000
99	16·2618	16·6162	16·9706	17·3250	17·6730	18·0309	18·3853	18·7448	19·0912	19·4456	19·8000
100	16·4260	16·7810	17·1420	17·5000	17·8515	18·2130	18·5710	18·9340	19·2840	19·6420	20·0000
101	16·5902	16·9518	17·3134	17·6750	18·0300	18·3951	18·7567	19·1232	19·4768	19·8384	20·2000
102	16·7544	17·1196	17·4848	17·8500	18·2085	18·5772	18·9424	19·3124	19·6696	20·0348	20·4000
103	16·9186	17·2874	17·6562	18·0250	18·3870	18·7593	19·1281	19·5016	19·8624	20·2312	20·6000
104	17·0828	17·4552	17·8276	18·2500	18·5655	18·9414	19·3138	19·6908	20 0552	20·4276	20·8000
105	17·2470	17·6230	17·9990	18·3750	18·7440	19·1235	19·4995	19·8800	20·2480	20·6240	21·0000

During the boiling considerable quantities of water are expelled as steam, and a great difference is consequently observed between the density of the wort after boiling, and the gravity which it indicated at the time of its introduction into the copper.

The annexed table, also by LEVESQUE, shows what gravity the original wort should possess to afford a gyle of a certain strength after one hour's boiling:—

Gravity required after one hour's boiling.	Gravity required in the raw wort.	Gravity required after one hour's boiling.	Gravity required in the raw wort.
8	6·60	27	21·60
9	7·20	28	22·40
10	8·00	29	23·20
11	8·80	30	24·00
12	9·60	31	24·80
13	10·40	32	25·60
14	11·20	33	26·40
15	12·00	34	27·20
16	12·80	35	28·00
17	13·60	36	28·80
18	14·40	37	29·60
19	15·20	38	30·40
20	16·00	39	31·20
21	16·80	40	32·00
22	17·60	41	32·80
23	18·40	42	33·60
24	19·20	43	34·40
25	20·00	44	35·20
26	20·80	45	36·00

As some brewers press the spent hops after the last mashing in order to secure all the liquor they contain, it is desirable to know how much of the worts is held by strained hops.

According to RICHARDSON, the volume of wort imbibed by the hops is as follows:—

Hops used.	Wort imbibed.	Hops used.	Wort imbibed.
Pounds.	Bar.	Pounds.	Bar.
1	0·01	30	0·50
2	0·03	40	0·66
3	0·05	50	0·83
4	0·06	60	1·00
5	0·08	70	1·16
6	0·10	80	1·33
7	0·11	90	1·50
8	0·13	100	1·66
9	0·15	200	3·33
10	0·16	300	5·00
11	0·17	400	6·66
12	0·19	500	8·33
13	0·21	600	10·00
14	0·22	700	11·66
15	0·24	800	13·32
16	0·26	900	15·00
17	0·27	1000	16·66
18	0·29	2000	33·30
19	0·31	3000	50·00
20	0·33	4000	66·66

The back into which the hops and wort are discharged is usually a large square vessel of wood or iron, with a perforated false bottom and a tap appended, not unlike the construction of the mash-tun. When the contents of the copper are to be drawn off, the "rouser," or other agitating apparatus, is set in motion to raise the hops in the liquor; and when the

whole is removed to the back, some time is allowed to elapse before the gyle is drawn off to the refrigerators, in order that the hops may subside, and retain any mechanical impurities which may be floating in the liquid as it filters through them.

Many brewers, especially in Scotland, instead of employing an apparatus like that above mentioned, erect a large square, with a temporary bottom or strainer, made of hair, and into this the hops and gyle are discharged. In this case the liquor is not so transparent as in the former; but it is held that the finer portions of the hop grains which are carried through with the coagulated albumen are serviceable as a preservative to the beer, chiefly on the ground that a larger quantity of albuminous and glutinous matter is deposited with the hop grains in the coolers, and that the gyle is therefore much better purified than by the practice of filtering through the hops, as in the first method.

Cooling.—After the worts are thoroughly hopped and boiled, the next thing to be done is to bring them to a proper temperature for the commencement of the fermentation, which, to insure success, must be conducted within certain limits. The liquor, in this case, must be rapidly cooled, for if permitted to remain too long in contact with the air, unless the atmosphere is very cold, acidity speedily occurs. Two methods are resorted to for cooling the worts. The first has been practised for a considerable period; but the latter, which is of recent introduction, is much more effectual, and is now most generally adopted.

The apparatus used in the first instance is known as the *cooler*, and in the second as the *refrigerator*.

In some small breweries the wort copper is placed sufficiently high for the wort to run from the hop back to the coolers, but in large breweries the wort copper is generally placed near the ground, and the coolers in the upper part of the building. In this case the wort has to be pumped up to the coolers from the hop back. The coolers must be placed in an airy situation, with louvre boards on all sides if possible, to cause a draught.

Coolers are spacious rectangular shallow vessels, for the most part constructed of Dantzic deal boards 2 inches thick at the sides, and $1\frac{1}{4}$ inch or $1\frac{1}{2}$ at the bottom; these boards are connected by plain joints, to which they are secured by pins of the same wood. The depth of the cooler is about 6 inches, and it should be perfectly smooth, so that no impurities can be retained, which would be the case when the worts are drawn off, were any inequalities or rough knots in the floor; it should have a gentle incline towards that end at which the gyle is discharged into the fermenting-backs, and be placed in a position where the air has free access to it. For this reason the cooling floor is always in an elevated part of the brewery, and exposed on all sides by means of louvre boards arranged in the same manner as a Venetian sun-blind, to create a draught. To expedite the work, various mechanical contrivances are used, to increase the current of air in the apartment, whereby the heat is more readily dissipated than if allowed to diffuse by radiation. The gyle is streamed upon this floor to the depth of 2 or $2\frac{1}{2}$ inches, and when the atmosphere is rather cold, as from the latter end of autumn to the middle of spring, the stratum cools in six to eight hours; but even this is too long a time for the liquor to remain exposed to the air.

Considerable loss, indeed, is often incurred by the imperfection of this method of cooling by the wooden floor, especially in warm weather, when the atmosphere is of a comparatively high temperature; for, in the first place, the liquor is not reduced in its heat so readily as to be entirely exempt from acidity; and, in the second, the wood of the vessel experiences considerable change in the alternate application of heat and cold, by which its pores are distended so much, that if allowed to remain exposed for any length of time air enters, and this coming in contact with the gyle in the next operation, it operates on its saccharine and albuminous constituents, and occasions a creaming of the surface, or an incipient fermentation, technically known as the "fox."

This evil may be partially prevented by keeping the floor covered with cold water, after the worts have been drawn off and the deposited matter cleaned away, till the next operation; but still the wood is liable to communicate acidity, unless the greatest attention be given to its being thoroughly washed very frequently with lime water.

Though generally made of wood, the coolers are occasionally made of other materials. A few years ago Messrs. Truman & Co., the well-known London brewers, erected some coolers made of sheet copper, which have turned out most satisfactorily; and no doubt the considerable expense of copper coolers is the only cause to prevent their general adoption.

When the brewer depended almost entirely upon the coolers for bringing his wort down to the required temperature, they required to be very large, and then coolers to the extent of 100 square feet area per quarter were needed; but refrigerators are now almost invariably used, and the coolers are much smaller and often 2 or more feet deep.

Fans are sometimes used for causing a draught for the wort when in the coolers. One form of fan is a vertical shaft fixed in the centre of the cooler, with horizontal arms on it near the surface of the wort, the whole being revolved by steam power. Fig. 17 represents a cooler with three such fans. In other cases a fan-blowing machine has been used, the blast being carried through a horizontal pipe placed right along one side of the cooler, having a slot along its whole length, through which the blast issues.

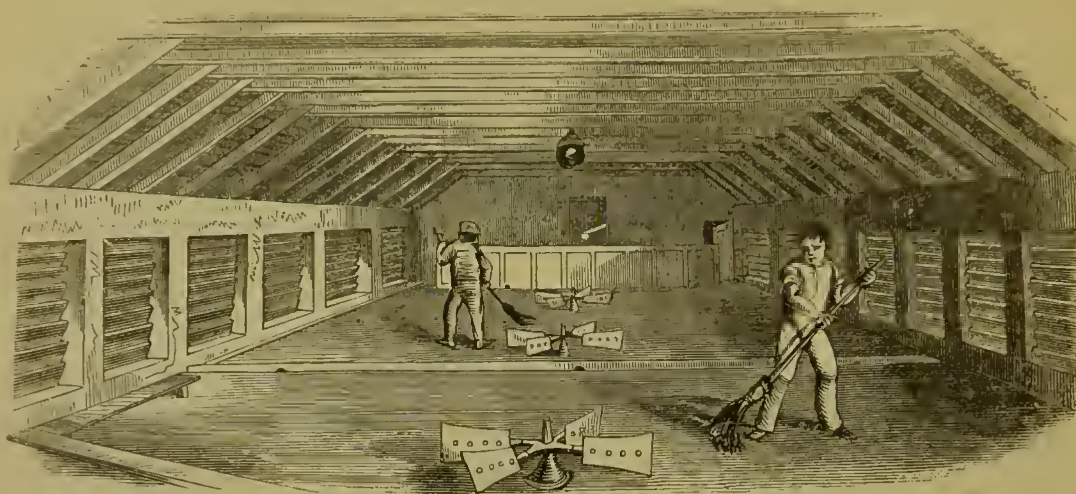
In some breweries coolers are entirely dispensed with, a sufficiently powerful refrigerator being used to reduce the wort to the necessary degree of coolness. There is no doubt that the use of refrigerators has great advantages over the old-fashioned coolers, both time and space being considerably economized by their employment.

The refrigerators occupy much less space than the plain coolers; they are sometimes constructed, like

the latter, in the form of a plane, with transverse divisions or bars issuing from each side alternately, and reaching to within half a foot of the opposite side; the space between each bar is usually about a foot or a foot and a half, and in this a pipe of suitable calibre is laid, through which cold water is made to flow in an opposite direction to the current of the gyle.

Fig. 18 represents the refrigerator in use at the brewery of Messrs. ALLSOPP & SONS; the water pipe,

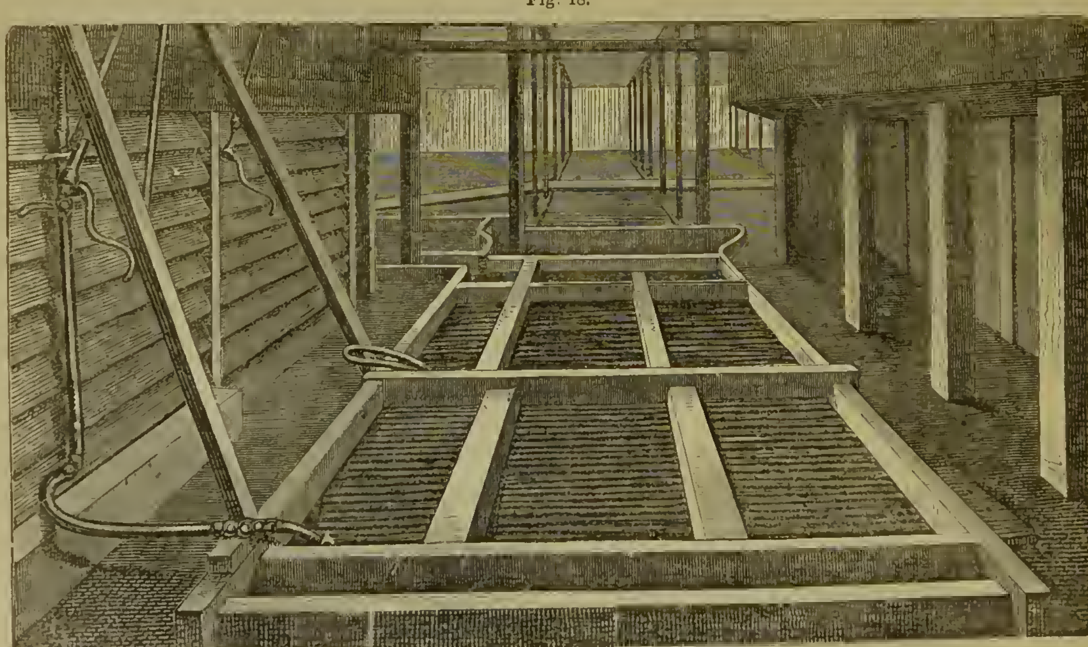
Fig. 17.



entering at the lower end, is seen at A, and passes off at the further end, where the hot worts are being discharged into the cooler.

During the last twenty years a great number of patents have been granted for refrigerators; but it will be sufficient to describe a few of those most generally in use. Compactness, durability, facilities for cleaning and repair, are points which must be considered in determining which is the best refrigerator, and unfortunately it is not easy to find any

Fig. 18.



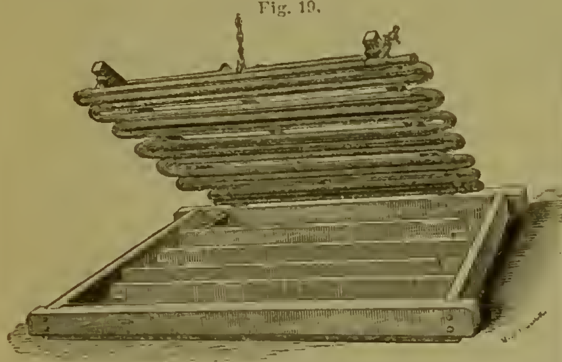
one refrigerator in which all these qualities are combined. There is also a great difference of opinion as to whether the wort should or should not be greatly exposed when being cooled; and it will be seen by the following descriptions that in some refrigerators the wort passages are entirely closed, and in others the wort is exposed during the whole time of refrigerating.

Previous to 1856 there was very little improvement in the form of refrigerators; that mostly in use (Fig. 19) consisted of a number of tinned copper pipes from 8 to 12 feet long, connected at the ends

by bends and laid horizontally in a wooden back or cooler about 6 inches deep. Between every third pipe was a wooden division joined to the back at one end, but not reaching the other end of the back by about 6 inches. This division made a channel for the flow of wort, the cold liquor passing through the pipes in a contrary direction. The pipes could be raised for cleaning, as shown in the illustration. This kind of refrigerator is still frequently used in small breweries, and is found to be good and serviceable for breweries up to about 8 or 10 quarters, or where coolers are used. But this form of refrigerator is only calculated to cool wort from a temperature of 90° Fahr. (32°·2 C.). For large breweries it is unwieldy; neither will it do when coolers are dispensed with, that is to say, when the wort enters the refrigerator at a temperature of about 150° Fahr. (65°·5 C.).

In 1856 G. RILEY patented a refrigerator that soon came into extensive use. It consists of a number of small block-tin pipes bent into horizontal coils lying one above the other, through which the wort runs. Between each circle is a metallic vertical division, forming a continuous passage, in which the cold

Fig. 19.



liquor runs in a contrary direction to that of the wort. The objection to this refrigerator is that brewers find it difficult to clean the pipes which convey the wort.

In 1859 BAUDELOT'S refrigerator was patented: it differs entirely from RILEY'S. BAUDELOT'S refrigerator consists of a number of copper pipes placed horizontally one above the other, and connected at the ends by bends, the under side of each pipe having a strip of metal on it with a saw-toothed edge. The wort to be cooled is delivered on the top pipe through a perforated trough, and trickles down the whole series of pipes, the cold liquor passing upwards through the pipes.

LAWRENCE'S refrigerator is similar in principle to BAUDELOT'S, but is different in construction, having corrugated sheets of copper instead of pipes.

In 1860 H. BRIDLE patented a very effective refrigerator. It consists of a copper case, open on the top, in which is fixed a series of thin flat copper pipes about $5\frac{1}{2}$ inches in depth and $\frac{1}{2}$ inch thick, at intervals of about $\frac{3}{4}$ of an inch. Each pipe is divided through its length into two $2\frac{3}{4}$-inch pipes, through which the cold liquor passes in two columns, one over the other, in opposite directions. The pipes are connected outside the case by metal boxes. The wort enters the case at the opposite end to that at which the cold liquor enters, passes underneath one pipe, rises to its level, and then falls over the next pipe; and so on, alternately over one and underneath the next till it comes to the end of the case, where it flows out.

The refrigerators of RILEY, BAUDELOT, LAWRENCE, and BRIDLE occupy but little space, and are suitable for cooling large quantities; RILEY'S and BRIDLE'S are small in height, but BAUDELOT'S and LAWRENCE'S are some feet in height, which sometimes operates against their adoption, since it necessitates the wort being pumped up to them.

Many other forms of refrigerators are made, but it is not necessary to describe them, as they do not differ greatly in principle from those mentioned, and the opinions of brewers differ so much on this point that it is difficult to assign to any pre-eminence for adaptability or utility.

When the worts are cooled on the open floor, considerable quantities of deposits are formed, which in some cases are swept off into the fermenting-backs. The chief aim of the manager should be to cool the liquor as rapidly as possible, especially when the temperature reaches 130° Fahr. (54°·4 C.). The floor and pipes should be kept most scrupulously clean, otherwise the goods will either acquire a very bad taste or turn acid.

The best materials for cleansing coolers are chloride of lime and quicklime, or a mixture of the two, but not bisulphite of lime. Chloride of lime contains oxygen in a form that can very readily be given up; whilst sulphurous acid readily absorbs oxygen. The bisulphite is, therefore, a very valuable cleansing agent when acetification only is feared; but when the "fox," *i.e.*, a putrescent fermentation, has to be got rid of, it is better to use a substance like chloride of lime, which oxidizes, or burns up and destroys the germs or other impurities causing the mischief. Of course, boiling water must be copiously used to remove the detergents employed.

The wort being now cooled to the proper temperature for fermentation, generally about 58° to 60° Fahr. (14°·4 to 15°·5 C.), it runs into the fermenting tun.

Fermentation.—In the whole course of brewing, there is no part of the work which requires such indefatigable diligence as the fermentation of the wort, as upon it depends the perfect accomplishment of the business. If the foregoing stages have been performed somewhat imperfectly, provided the products have not acidified, if they are subjected to a good fermentation, a wholesome beverage is obtained; but let the mashing and the other operations be ever so studiously executed, if the fermentation is imperfect, a bad and almost worthless product results. By care and moderate experience, however, brewing may be easily so managed as to guard against the possibility of a failure.

The theory of fermentation of LIEBIG, GAY LUSSAC, GERHARDT, MÜLDER, and others is, that

under certain conditions a nitrogenous body, having an albumenoid character, breaks down and decomposes; its equilibrium is disturbed, and in that disturbance it is able to communicate a disturbance of equilibrium to the sugar molecule that may be found near it. Hence, therefore, they consider that the process of fermentation is entirely a chemico-physical one. GAY LUSSAC held that the oxidation of albuminous matter was an essential feature of the process; and this is to some extent true, only that, as already stated (see ALCOHOL), fermentation will go on even when no air is present. At the same time, air does seem to start the fermentation process. The other and now generally adopted theory is due to SCHWANN, a German chemist and physiologist, who, about the year 1836, maintained that there was no real case of fermentation unless cells of living organisms were present, and that these were the agents of the change. Hence, therefore, arose the theory of its being a vital phenomenon.

Later on PASTEUR took up the subject and worked at it with that wonderful energy and scientific acumen for which he is so distinguished. His experiments were carried on for years, and proved fully that fermentations are the results of vital processes. He maintains that the alcoholic fermentation is not due to the decay, to the putrefaction of the cells, of which yeast is composed, but is due to the action of the living and growing organisms. It has been objected that diastase, and many animal secretions, are able to convert starch into sugar; and not only that, but when alcohol is acted upon by oxygen in the presence of platinum black, the alcohol is oxidized first to the state of aldehyde, and then to the state of acetic acid, these phenomena being held to be distinctly phenomena of fermentation. But from PASTEUR's point of view the conversion of starch into sugar is not a case of fermentation at all, since dilute sulphuric acid can at 212° Fahr. (100° C.) effect the same change. Acetic acid is also, under certain conditions, obtained from alcohol; but no purely physical and chemical means has as yet been found by which sugar may be converted into alcohol. So far, therefore, the weight of evidence rests with PASTEUR, viz., that true fermentation is solely brought about by living organisms.

The organisms which cause the alcoholic fermentation are commonly known as *mycoderma cerevisiæ*. The term *Torulæ* has also been applied to the true yeast germs, to distinguish them from another kind of germs which are also found in the wort, and which cause, from the brewer's point of view, a diseased form of fermentation. These are called *Bacteria*.

The *bacteria* are very various in form. Some are tubes from 1-15,000 of an inch up to 1-2,000 in length, divided by a little septum or division in the middle into two equal parts. They are sometimes stationary, but as a rule they are darting about the liquid with great rapidity. The process of reproduction in the *bacteria* is generally that of simply dividing into halves.

The size of the *torulæ* vary from minute specks up to the 1-2,000th of an inch in length. Their mode of reproduction is by germination. First, a little projection appears on the cell, which gradually gets larger, and finally a bud is formed, which separates from the mother cell.

The German brewers have long thought that the *torula* cells were reproduced by a process of emission of spores, and that these spores were carried by carbonic acid through the gyles into the air.

PASTEUR has discovered a method of growing *torula* germs only, so that the brewer can have pure yeast, uncontaminated with *bacteria*, the "*maladie de ferment.*"

He directs a solution of sugar to be added to a sample of ordinary yeast. The yeast ferments, and after it has finished fermentation, or very nearly so, the supernatant liquor is to be poured off and a fresh solution of sugar added. This is repeated two or three times. During this process the cells become weak and wanting in vigour. They are then placed in a bottle or closed vessel, and a little wort which has been previously well boiled added, in order to reinvigorate them. A new crop of cells is thus obtained, containing no *bacteria*. The next stage in the process is to grow a larger crop of yeast. This is done by setting up fermentation with some of the pure yeast in a vessel cleansed by steam, and which is kept charged with carbonic acid, perfectly free from germs, to exclude all atmospheric spores.

Yeast can be kept very pure by taking care to ferment only at low temperatures. This may be done with such a portion only of the wort as is sufficient to yield enough yeast for the whole of the brewing. Care must be taken not to use the scum or the unsound and foul yeast that first comes off.

Yeast is very variable in its effects, according to the time of its production, its succeeding management, its age and condition; to excite energetic fermentation it cannot be too fresh. The best yeast is collected from pale gyles, near the close of the alcoholic fermentation, and after the first or second skimming. The first portions of yeast thrown off are not sufficiently solid, and besides generally contain some of the glutinous matter which has not been wholly transformed into yeast. It is therefore liable to undergo further oxidation, and to set up an acetous or putrefactive fermentation. It is needless to add that such yeast would be highly injurious, and ought to be avoided.

When collected as above described, it is sufficiently dense, contains no glutinous matter which has not undergone oxidation, and is, besides, wholly free from the old store or ferment added to the liquor in the beginning of the fermentation. It has also the great advantage (in accordance with PASTEUR'S theory) of having been entirely protected from contact with atmospheric germs during its formation. By using the yeast thus carefully prepared, a much less quantity of it will be effectual than of the other kinds which may be taken at random.

Yeast should be washed and pressed, and kept in a closed vessel and cold. German brewers, when they are not able to use it at once, press it, mix it with

sugar, and put it into a vessel which is closed and kept cool. The state of the yeast should invariably be investigated by the microscope before using, that if it contains many *bacteria* it may be rejected.

Dr. C. Graham gives the following ready method of ascertaining the comparative potential energy of samples of yeast. Take a sample of wort, using half a litre for each given experiment, and place this quantity of the same wort into the respective fermentation bottles. Then weigh 2 grammes of each sample of yeast after pressing them between blotting paper to remove the moisture (this is equal to about 2 lbs. per barrel), and add them to the respective test bottles. The apparatus in each case is then closed. It consists of a bottle with a short tube passing through the cork, but which does not go down to the liquid. It is connected by a piece of india-rubber to a long tube, which also passes through a cork into another bottle, but does not touch the liquid. In the second bottle there is a long tube which passes down to the bottom of the liquid, and then comes up and passes into a measure glass, and in the measure glass it also goes down to the bottom. When the action is started, fermentation is set up more or less vigorously, according to the energy of the yeast, and carbonic acid is produced. Now, carbonic acid may be taken with very great accuracy as a measure of the energy of the fermentation. The carbonic acid passing through this tube presses the top of the liquid in the second bottle, which is a saturated solution of common salt; the object of using which is, that this liquid shall not dissolve much carbonic acid. As it presses this, it drives some of the liquid into the graduated glass. The conditions of the experiments are the same in all the cases, so that it is easy to decide in the course of twelve hours to twenty-four as to the respective decomposing powers of the yeast. When the fermentations are started the bottles must be kept in the same place, so that they may be subject to the same temperature. (*Society of Arts Journal*, vol. xxii. p. 300.)

The principles of the vinous fermentation have already been described at sufficient length (see also Alcohol). It is worth observing, however, that there are various other species of chemical decompositions, commonly characterized by the term fermentation, in which by direct or indirect oxidation certain compounds are generated. According to the nature of the substances operated upon, one or more of these fermentations may be excited by the contact of a body undergoing the like decomposition. For instance, a compound in the state of the acetous or lactic fermentation, on being brought in contact with a solution of sugar, occasions the direct formation of either acetic or lactic acid in the liquid.

This being the case, it is evident that the greatest and most scrupulous care should be observed in selecting the "barm," or "store," which is employed to induce the vinous fermentation in the wort, lest it may have contracted any acidity or putrefaction, which would certainly prove detrimental to the beer, by setting up the lactic or acetic fermentation, and thus deteriorating its flavour, wholesomeness, and keeping properties.

The apparatus required for the fermentation are either circular tuns or squares, constructed of sheet-iron or Dantzic deal, and of a capacity suited to the quantity of materials employed; they are generally furnished with an attemperator, or pipe, through which either hot or cold water, as the temperature of the contents may be too high or too low, is transmitted. These vessels will be fully described later on.

The liquid is introduced into the fermenting tuns at a temperature varying from 54° to 64° Fahr. (12°·2 to 17°·7 C.), according to the practice of different brewers. In England the pitching heat is usually between 60° and 64° Fahr. (15°·5 to 17°·7 C.), or even higher; while in Scotland the temperature, except in some few cases, does not reach higher than 58° Fahr. (14°·4 C.). When the pitching heat is high, and the yeast is of a good quality and in sufficient abundance, the fermentation proceeds so rapidly and with such energy that it becomes ungovernable; some means must therefore be employed to check the heat. For this purpose coils of pipe, through which water circulates, are fitted up in the tun. Unless this is done the whole of the glutinous constituents of the gyle is not removed in the yeast, and the liquor does not cleanse satisfactorily, in consequence of an after fermentation which sets in, which is technically known as the "fret."

On the other hand, if the action proceeds sluggishly, so that the yeast remains in contact with the liquor at a temperature of 66° to 70° Fahr. (18°·8 to 21°·1 C.) for some time, then, in addition to the beer being ropy, it will retain the disagreeable taste of the yeast, that has to some extent entered upon the putrefactive fermentation. The beer is in this case termed "yeast bitten."

To guard against both these serious evils, it is necessary to be scrupulously careful that the store yeast is in a good and healthy condition, and also that the temperature is properly regulated, as well in reference to the bulk and gravity of the gyle, as to the state of the atmosphere. The practice observed by some brewers of beating the head of the yeast into the gyle, however it may seem to favour the operation, is not so indispensable as they would suppose; for if the action be engrafted in the liquid at the first, it will proceed with sufficient power to complete the work without the assistance offered by the new yeast being beaten into it.

Keeping these considerations in view, the brewer may discharge his worts into the fermenting vessels at from 58° to 64° Fahr. (12°·2 to 17°·7 C.), according to the conditions already alluded to; but before he proceeds he should ascertain the mean temperature of the air in the room, and note the real density of his gyle, and the quantity in barrels and firkins, so that he may be better able to judge of the rise of temperature, the degree of attenuation, and the waste suffered during the action; and above all, the proportion of yeast or "store" to be added at the commencement. Various circumstances tend to influence the quantity of yeast which ought to be added

to the gyle; hence, to give a definite rule in this particular is out of the question. By studious attention and moderate experience the brewer will be able to master the difficulty, especially when it is borne in mind that the variation takes place, first and principally, with the quality of the store; secondly, with the degree of heat at which the malt had been dried, and the quality of the liquor used in mashing; thirdly, with the gravity of the worts; and fourthly, with the temperature of the liquor, and likewise that of the air at the time of pitching the tun.

When starting fermentation, if highly dried or patent malt has been used, the yeast must be added in larger proportion than if the worts were extracted from pale malt, for the constituents of the grain undergo decomposition, in consequence of which the proportion of gluten is considerably reduced in the extract; and to make up this deficiency of matter by which new ferment is formed, and the action of the original ferment invigorated, a larger proportion of yeast must be supplied in the first instance. The same precaution must be observed when the temperature of the gyle is low, and a large amount of extract is present. The temperature of the liquor and air at the period of fermenting will greatly influence the rapidity of the fermentation; for when the degree of heat is elevated, the matter of the gyle will more readily commingle.

When the gravity of the gyle is about 45 lbs. per barrel, and the temperature of setting 58° or 60° Fahr. (14°·4 to 15°·5 C.), the atmosphere being at the ordinary temperature and barometric pressure, provided the yeast be of good quality, about 2 to 2½ lbs. per barrel will be sufficient, and it may happen that this quantity may in some cases overstore the tun. In winter, on the contrary, the store per barrel is increased to 3, and sometimes 3½ lbs.; but then the heat of pitching is lower than in the preceding case.

When worts of 20, 25, 30, or 40 lbs. per barrel—the usual strength of the ordinary ales—are fermented, a less weight of store must be added in proportion as their density decreases.

The intervals of adding the yeast, like the various other operations in brewing, are different with most brewers, some preferring to add the total quantity at once, while others reserve a portion to be subsequently introduced in order to strengthen the fermentation. As in either case the results are satisfactory, the brewer must be left to his own discretion in this matter, being mindful, however, that it is necessary to have a healthy action inoculated in the gyle from the beginning, otherwise the fermentation will not be successful.

After the mixture of the yeast and gyle has been made some time, some minute bubbles of gas rise to the surface, and form on the sides of the vessels; as the operation advances, this ring of minute vesicles, or froth, as it is termed, becomes detached, and moves towards the centre, its place being in a short time occupied by another ring, which imitates its predecessor, and thus the rings succeed one another till the whole surface is covered.

As the decomposition of the sugar becomes more rapid, the liberation of carbonic acid is freer and more voluminous, and a hissing sound or effervescence is observed. The froth swells to a larger extent by retaining the carbonic acid in the viscid matter which rises to the top. At length the volume accumulated is so great that the tension of the yet imperfect yeast cannot restrain it, it bursts and causes inequalities in the head, which gives it the appearance which the brewer terms "rocks."

The froth, which hitherto was colourless, begins to be tinged yellow, and as the work proceeds it turns either to a lightish or brownish yellow; but it is a better sign of the fermentation if it remains of the former shade.

The yellowish brown colour is mainly due to the decomposition of a peculiar glucose compound with the resin of the hop. The glucose is broken up, and forms alcohol and carbonic acid, and at the same time the resinous matter which was previously associated with the sugar is liberated.

At this period of the process the head falls considerably, in consequence of the carbonic acid gas which accumulated during the preceding part of the operation overcoming the elasticity of the yeast and escaping; the newly-formed yeast becomes more dense and viscid, and the fermentation is much diminished. Were the head permitted to remain in contact with the liquor after this period, it would very soon precipitate, and probably, by itself entering upon a putrefactive decomposition, would give rise to the same in the liquor; at any rate, the disagreeable bitterness which characterizes stale or putrefying ferment would be discernible in the beer, and in this state, as already remarked, it is said to be yeast-bitten.

To prevent the pernicious effect of yeast-bite the ferment is skimmed off, and the fermentation is also checked so as to prevent it from passing the desired limits; many brewers, however, take off only the top surface, beat the remainder into the liquor, and continue the fermentation with renewed vigour, till all the albuminous matters are separated in the form of yeast, and the greatest part of the sugar has been converted into alcohol and carbonic acid. Such is the treatment usually applied to exported ales, or bitter beers that are reserved for store.

Yeast-bite is due to the action of the alcohol formed, not upon the living but upon the dead yeast cells, and upon the resinous matter separated in the decomposition of the glucose.

After a time the fermentation is attended of course with an attenuation of the wort. The amount of attenuation in this country is to the extent of about two-thirds of the original gravity of the wort; in some cases it is even carried down to three-fourths. The amount of work done depends of course to some extent upon the amount of yeast produced, and the amount of yeast production varies with the fermentation itself. It depends, in the first place, upon the temperature, for the higher the temperature within a given range, the more active is the production of the cells; it depends also upon the

amount of hops used, for the less hop the more vigorous the cell growth and chemical decomposition. It depends also upon the amount of glutinous matter found in a soluble condition in the wort, *i.e.*, the amount of *food* supplied to the yeast germs. It also depends upon the amount of kiln drying to which the malt has been originally submitted; and lastly, it depends on the actual reproductive energy of the yeast cell itself.

When the fermentation flags, various plans are adopted to overcome the difficulty of the fermentation standing still. One of the simplest plans is to add more yeast, but probably enough yeast may have already been added. The other plan which is very much used is to add some ground malt. A large quantity of soluble albuminous matter is thus supplied, and the probabilities are that the action of the ground malt is not that it supplies sugar, because there is enough there, but that it supplies the yeast with a quantity of readily assimilable albuminous matter.

In brewing mild ales it is necessary to have a certain quantity of the sugar unattenuated, in order to give more or less sweetness to the beverage, and therefore the barm is skimmed off, as above stated, to check the fermentation, and attain the end proposed.

HORACE BROWN, in his researches on the influence of pressure on fermentation, has recently found that hydrogen and nitrogen gases are invariably liberated, and a certain amount of acetic acid produced. And this although he took special precautions that there should be no possible access of oxygen to the liquid. The presence of this hydrogen and nitrogen indicate that the decomposition is not so simple as had previously been supposed. BROWN performed a great number of experiments, and derived the following conclusions from them:—In the first place, the fermentation products are not only alcohol, carbonic acid, glycerine, succinic acid, and acetic acid, but there are also hydrogen and nitrogen gases given off. Secondly, that as the amount of nitrogen is decreased the amount of hydrogen is increased. (The nitrogen is of course the product of the decomposition of albuminous matter). When the amount of hydrogen is increased in this way, he also observed an increase in the amount of aldehyde and in the amount of acetic acid. The formula of aldehyde and alcohol are C_2H_4O and C_2H_6O. By taking away two atoms of hydrogen from alcohol aldehyde is formed; and by adding one atom of oxygen to the aldehyde acetic acid, C_2H_4, is obtained. Thirdly, he found that water is decomposed by the yeast organisms in the process, and that their power to decompose water was facilitated by a reduction of the pressure. Fourthly, he observed that on reduction of the pressure a less amount of sugar was decomposed, but that there was a greater amount of that which was decomposed converted into acetic acid and into aldehyde.

Fermenting Tuns.—When the wort is run into the fermenting tun, yeast is added to induce fermentation. The fermenting tun must be of sufficient capacity to contain the whole of one brewing or "gyle," with additional depth to allow room for the yeast formed in fermentation. The proportions of the fermenting tun are not very important. Most brewers prefer it to be a cube. It may be either circular or square. It is generally made of fir, though during the last few years slate has frequently been used on the score of cleanliness. Glass has recently been tried, but there is considerable difficulty in keeping it sound.

As it is very important to keep an even temperature during fermentation, every fermenting tun should have an attemperator, consisting of coils of tinned copper pipe, usually supported by brackets from the sides of the tun, one above the other, or side by side. Two or more coils of pipe are required, according to the size of the tun, to get the requisite surface. The brackets are sometimes made of galvanized iron, but many brewers prefer keeping iron out of fermenting tuns, and therefore use tinned gunmetal brackets. Occasionally, and especially in small fermenting tuns, portable attemperators are used, which are raised or lowered at pleasure by a cord or chain.

The attemperator is supplied with cold liquor, and when the temperature of the beer is rising a small stream is allowed to flow through the pipes; the main object of the attemperator being to check an increase of temperature, as if the beer is permitted to get too hot the mischief is done, and is not rectified by its being cooled down afterwards.

According to the old method of brewing the beer was kept in the fermenting tuns for about three days, and the fermentation was afterwards completed in cleansing casks (these will presently be more particularly described); but of late years "skimming" has much come into use, by which method the fermentation is completed, or very nearly so, in the fermenting tun.

"Skimming" consists in removing from the surface the yeast that has formed; this may be done by hand, but it is an unsatisfactory method. The best mode of clearing away the scum is by the skimming apparatus represented in Fig. 20, which effectually accomplishes the operation with cleanliness, certainty, and ease.

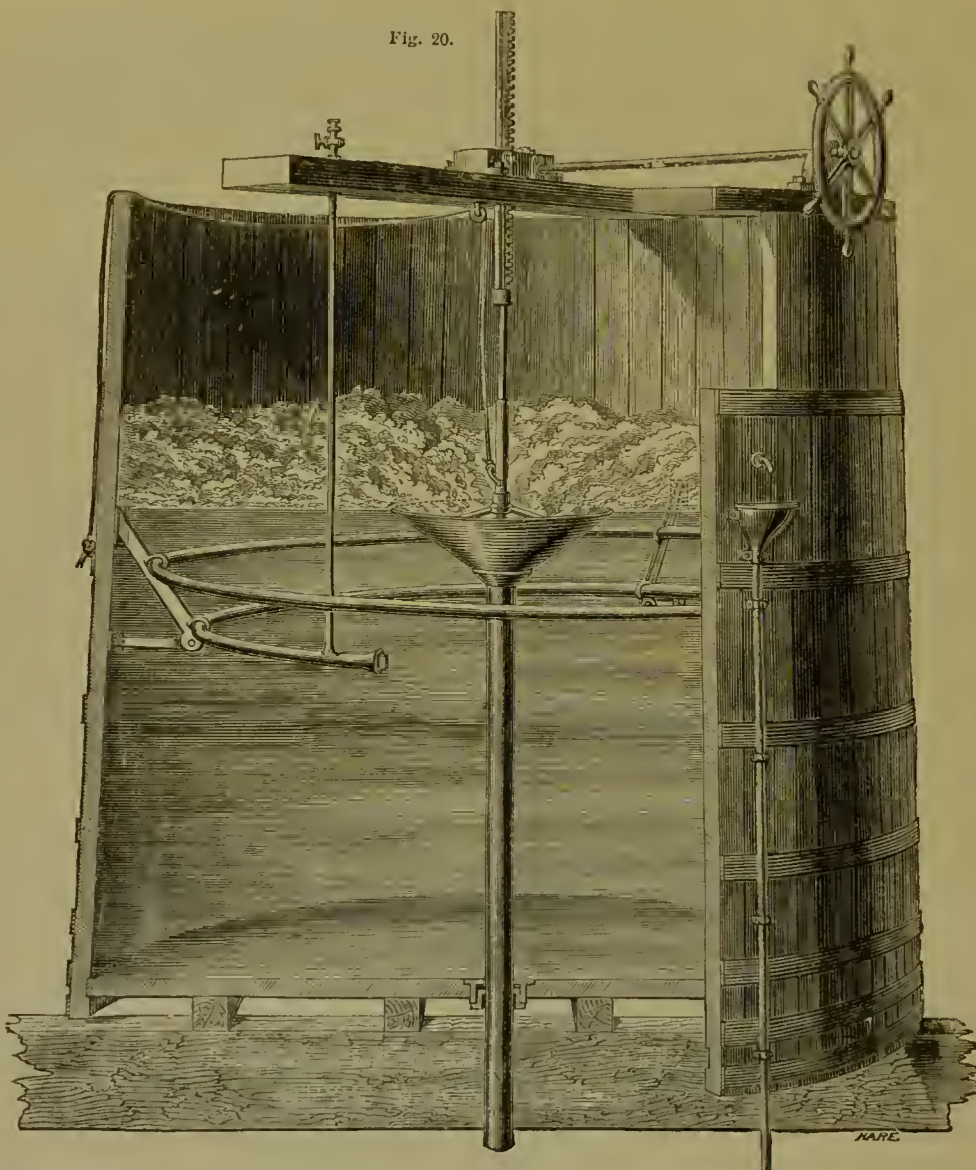
The apparatus consists of a tinned copper basin with a valve in the centre, and a turned brass tube which works in a stuffing box fixed in the bottom of the tun. The whole of the apparatus is raised or lowered by means of a rack and pinion, or a screw, worked by a handwheel at the front of the tun. The edge of the basin is thus so set that it is very slightly above the level of the beer. As the yeast forms it falls over into the copper basin, and is let off at pleasure by pulling a cord attached to the valve, it then passes down the brass tube into a yeast trough below.

Fig. 20 shows a fermenting tun with fixed attemperator and skimming apparatus. The number of fermenting tuns required in a brewery is regulated by the frequency of brewing. Where skimming is not adopted the beer remains in the

fermenting tun about three days; but if skimming is practised, for about double that time. The position of the fermenting tuns must be such that the beer will run into them from the refrigerators; and they must be high enough from the ground to give height underneath for the cleansing casks. Each fermenting tun is provided with a discharge cock, through which the beer, when properly fermented, is run off.

The double fermenting square is a contrivance which has acquired some celebrity in Yorkshire and the adjoining counties. It consists of an inner close square, with an exit pipe from the cover, through which the barm escapes. In this the worts are inoculated with the ferment, and the space between its walls and those of the exterior square is filled with cold water, by which the temperature of the

Fig. 20.

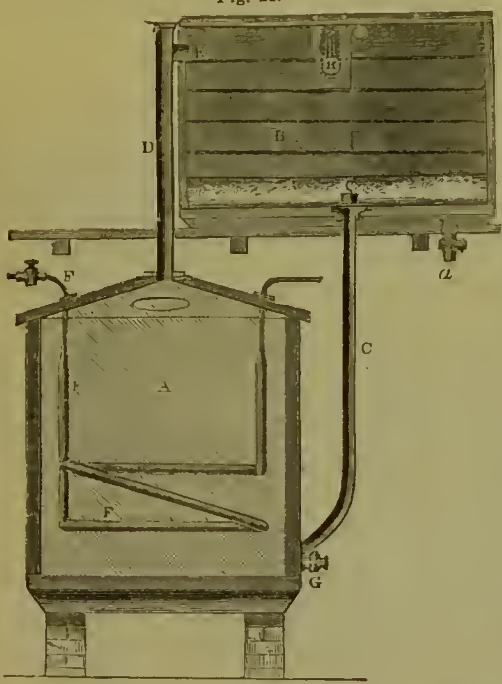


enclosed liquor is maintained at a low point, and hence the fermentation, though slow, is more sure in its effects. It is controlled, however, with much difficulty in the summer time, when cistern or surface water acquires a heat of between 60° and 70° Fahr. (15°·5 to 21°·1 C.), unless there is sufficient spring water at command. The brewer endeavours to keep the fermentation at about 62° to 64° Fahr. (16°·6 to 17°·7 C.) till the attenuation has been continued as far as is desirable; then, by transmitting cold water into the exterior chamber, as well as through an attemperating pipe placed in the liquor, he reduces the heat to about 56° Fahr. (13°·3), at which degree it is maintained during the cleansing.

The annexed simple arrangement, Fig. 21, represents the fermenting square of Messrs. Walker and Son, of Warrington, Lancashire. It consists of two squares, both air-tight; one, A, in which the fer-

mentation is carried on, and the other, B, for collecting the discharged yeast. Both are connected by a pipe, C, which descends from the bottom of B and enters A at the front near the base. Through this pipe the gyle, as well as the yeast, is admitted into the square, completely filling it; well-fermented ale is then poured in, till there is a layer of about 2 inches in depth on the bottom of the yeast-receiver. As soon as the fermentation commences, and the yeast, as yet frothy and partially formed, begins to be discharged, it rises through the pipe, D, issuing from the top of the bevelled cover, and is discharged into the yeast-receiver at E. As the semifluid matter comes off from the lower vessel, the layer of beer in the yeast-receiver descends in its stead, and maintains the proper level, leaving the bottom of the latter still covered to the depth of 1 or 2 inches by the liquor received from the lower tun, and thus preventing

Fig. 21.



the froth from again passing into it. In this way the operation is conducted till finished. When the heat of the liquor is too high, it is controlled by the transmission of cold water through the attemperating pipe, F. Another cylinder, H, through which a stream of cold water is passed, keeps the air in the covered yeast-receiver sufficiently reduced in temperature, thereby arresting to some extent the evolution of the carbonic acid gas arising from the action of the fermentation. This, to all who are conversant with the subject, is known to be very valuable in securing the soundness of the beer, and giving it a tone of warmth, besides rendering it pleasant and agreeable to the palate.

At the termination of the fermentation the yeast, which is accumulated entirely in the square, B, is collected by drawing off the layer of liquor which covers the bottom of this vessel, by means of a hose attached to a pipe, seen at *a*; and when this is done the barm is brushed out through a plug-hole near one of the corners, and passed along a hose into proper vessels. Should the yeast accumulate in great abundance in consequence of an excess of gluten in the gyle, then, by the same course as the preceding, it may be swept out and the ale drawn off, pumped up once more, and the fermentation continued till finished.

The heat of the fermenting liquor is under complete control, and may be retained at any degree, provided well-water is at hand.

This system of fermentation dispenses with the watching and hand labour usually required, and saves an immense amount of space in fermenting a large quantity, on account of the compactness of the apparatus. At the close of the operation the liquor, after being cooled by means of the attemperating pipe, F, is ready to be drawn off through the tap, G, into barrels or hogsheads, and at once sent to the consumers, in consequence of the yeast being continually removed during the operation. Messrs. Walker use 12 ounces of barm to each barrel of wort.

Another great advantage of this system is found in the fact that no such taint as "yeast-bite" can ever be discerned in the liquor.

It has been shown on several occasions that, when the vinous fermentation takes place in a liquor, it is always succeeded, provided the liquor be left to itself, by the acetous fermentation. It is the same in the present instance; for if the fermented wort were allowed to repose after the first action has ceased and the product clarified, it would in a very short time become again turbid, absorb oxygen, eviscerate a mucilaginous matter (*mother of vinegar*), and turn sour. This further fermentation is prevented by the cleansing process.

Having thus enumerated the principal methods of inducing and regulating the fermentation, the next process in brewing is now entered upon.

Cleansing.—After the fermentation in the tun has flagged, and the chief portion of the yeast has been removed by skimming or otherwise, particles of yeast and glutinous matter still remain held in mechanical suspension in the body of the beverage, and give it a muddy appearance. Could these be even removed by filtration the liquid would still appear muddy, since the fermentation has not completely ceased; and as long as this lasts fresh particles of yeast will be generated, and these will keep the liquid turbid and impure.

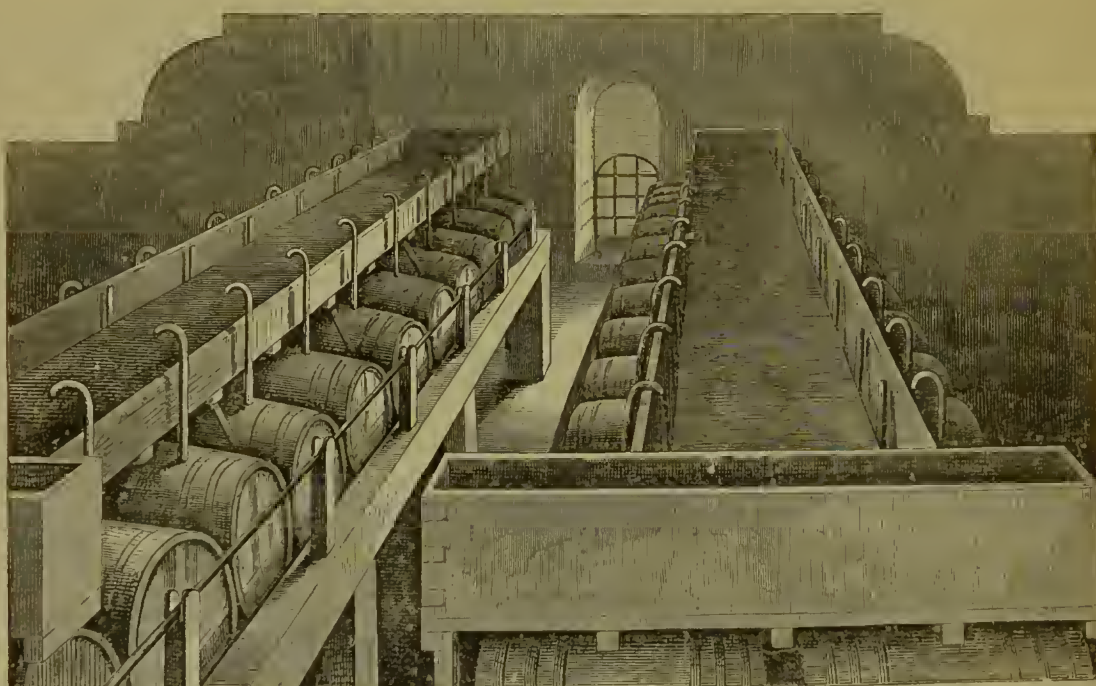
"Cleansing" is effected in a variety of ways; the oldest method, which is still extensively practised, is to run the beer from the fermenting tun by means of a hose into ordinary casks laid side by side on a trough, or stillion, about 2 feet high. The beer remains in these casks for several days, the bunghole being left often, and through it what little yeast remains in the beer works out and falls into the stillion. When the discharge of yeast ceases, the beer is ready to be bunged up and put into store. It may here be mentioned that beer is sometimes pumped

from these casks and stored in large vats; but that system is now getting very much out of use, as the popular taste is more for mild than old beer.

The cleansing, when properly performed, is a very important stage; the distribution of the attenuated liquid into small portions has the effect of reducing the fermenting action considerably—so much so, that if the attenuation has not been sufficiently advanced at the time of racking off into the cleansing vessels, very little can be effected in them, and the liquor will remain too sweet. To prevent this, many brewers either briskly agitate the contents of the fermenting square, to raise the yeast which may have been deposited on the bottom, or add a fresh quantity of the ferment to it, and rummage the whole with an apparatus fitted in the tun for the purpose, or by any other contrivance. In either case, the object is to give the ferment a fresh stimulus, in order to counteract in some degree the checking influence of the racking into small quantities, whereby the temperature and other conditions that aid in converting the sugar into alcohol are not a little reduced. It would, however, be better to push the fermentation so far in the tun, that only enough of saccharine matter will remain to give to the liquor sufficient body, and also, by its slow fermentation, develop so much carbonic acid as to keep it sparkling and refreshing.

In the extensive breweries of Messrs. Bass and Allsopp the cleansing is very effectually performed, and for this reason a description of their method will here be given. As already stated, the cleansing has for its object the arresting of the fermentation and the separation of the yeast, and this is effected by

Fig. 22.



transferring the beer into smaller vessels, where it remains till the clarification is complete.

At the above firms a number of casks, amounting to 800 or 900, each capable of holding four to five barrels, are placed in the cleansing-room. These are suspended in sets of ten or twelve on a substantial frame, so as to admit of a free revolution of the casks on their axes. Above these a large wide open trough—the yeast trough—is placed, with which each of the casks beneath communicates, first, by a movable or sliding tube, and secondly, by a head pipe, usually called a "swan-neck:" the former connection can be cut off at pleasure by a wooden plug. Diametrically opposite these two outlets a tap is screwed into the casks, and through this the liquor is drawn off when ready for racking. Immediately below these taps another trough is erected along the whole range, and the liquor is by this means conducted into the racking squares. At one end of the superior trough there is a small reservoir, capable of holding 5 or 6 barrels of liquor, and called the "feeder," in consequence of its being connected with each of the casks by a small pipe running parallel with their ends, and branching off into each; by this means the liquor which separates by evaporation, and also the yeast, are replaced from the reservoir.

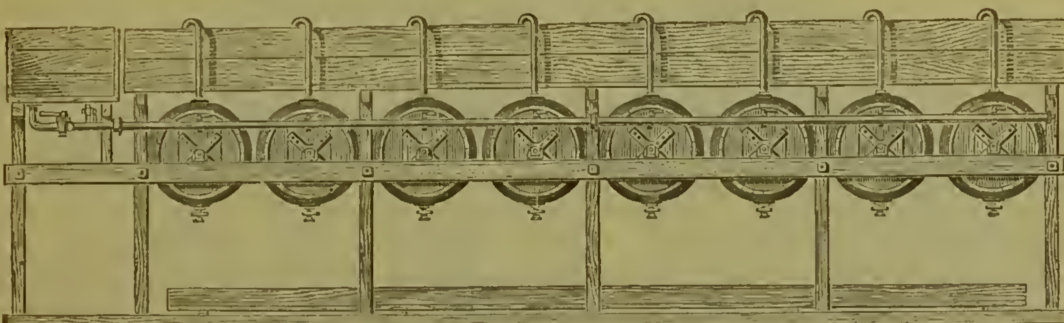
Fig. 22 more fully explains this arrangement.

The following is the method of working the apparatus:—The ale to be cleansed is pumped into the large yeast trough, and then run into the casks through the sliding tubes; when the cask is quite full this communication is stopped up with the wooden plug mentioned before, leaving only the swan-neck outlet free. Through this pipe the froth arising from the fermentation forces its way, and is transferred to the yeast trough, where the yeast is deposited.

To keep the casks full, and to enable the froth to rise to the yeast tun, a quantity of liquor is put into the reservoir, and thence conducted into the casks by the pipe already mentioned. After the fermentation has continued in this state for one or two days, it apparently subsides altogether; the contents are then permitted to remain at rest for a few days longer, for the purpose of affording any yeast that may not have ascended to the trough, time to precipitate to the bottom. The clear ale is then drawn off by means of the screw tap inserted in the lower part of the casks. By turning this tap the interior sucker is so far elevated as to be above the dregs, and therefore none of the impurities are carried off in the liquor, but remain in the casks.

The system of cleansing by union cleansing casks, as commonly employed, is shown in Figs. 23 and 24. The casks usually hold about three barrels each, and a sufficient number of them is arranged in each set to contain one brewing. The casks are mounted end to end in double rows, on a wooden frame about 2 or 3 feet from the floor. Each cask has on both heads an iron cross with a projection which rests on an iron bearing screwed to the wooden

Fig. 23.



frame, so that it may revolve after the manner of a churn. The bunghole of the cask is upwards, and in it is inserted a turned copper "swan neck" pipe, about 2 feet long, which turns over into a wooden yeast trough that runs down the whole length of the set of casks. At the end of the yeast trough is a feed back, into which the beer runs from the fermenting tun. From the feed back run two copper pipes, each along the heads of each row of casks. At each cask there is a cock in the main, through which the beer is admitted into the cask. The casks being filled, the quantity of beer necessary to fill up the casks from time to time is left in the feed back. The yeast works up through the "swan neck" pipes, and falls into the yeast stillion. At the bottom of each cask, directly underneath the bunghole, there is a discharge cock,

Fig. 24.

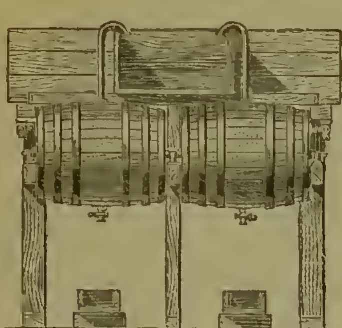


Fig. 25.

through which the beer, when finished, is delivered into a wooden or copper trough that runs underneath the casks. The beer then runs into a settling back, or racking vessel, where it is allowed to settle for a short time before being drawn off into casks for sending out. By detaching the connections from union casks they can be washed in their places by having some liquor run into them, and then being revolved.

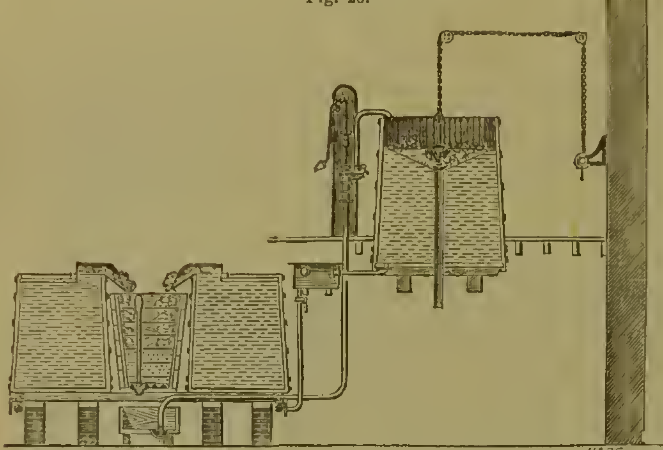
Union cleansing casks are not very much used, except in the breweries at Burton-on-Trent; but there they are extensively used, Messrs. BASS & CO., Messrs. ALLSOPP & SONS, and other large brewers there, having many hundreds of them.

Another system of cleansing, principally adopted by the large porter brewers, is to use pontos (Figs. 25 and 26). These are vessels made in the shape of vats, and containing from four to ten barrels each. The pontos are placed in a double row, with a yeast stillion between them. The beer is run into the pontos, and the yeast works out through an opening in the head into the stillion. The feed back is a similar vessel, and furnished with a skimming apparatus the same as that described for fermenting tuns.

In other respects pontos are worked in precisely the same manner as union cleansing casks. The general arrangement and mode of working can be seen by a glance at the accompanying Figs. 25 and 26.

A simplified form of the principle of union cleansing casks is shown in Fig. 27. It is entirely self-acting, and by its use manual labour is dispensed with in tunning the beer and filling up. By this method also ordinary casks may be used. Each cask is furnished with a brass nozzle fitted into the bunghole, from which a small copper pipe descends to nearly the bottom of the cask. At the upper part of the pipe is attached a short piece of india-rubber hose, which slips on to the nose of a cock fixed in the yeast stillion placed above the casks. From the same nozzle a tinned copper "swan-neck" pipe stands up and turns into the stillion. The beer, when ready for cleansing, is turned into the stillion. As many casks as may be desired are charged at one time, and are kept filled up until the beer has done working, the pipes in the casks carrying the beer towards the bottom, and the swan-neck pipes delivering the yeast into the stillion. The cost of this apparatus is very considerably less than that of union cleansing casks, and its action is generally considered to be as good.

Fig. 26.

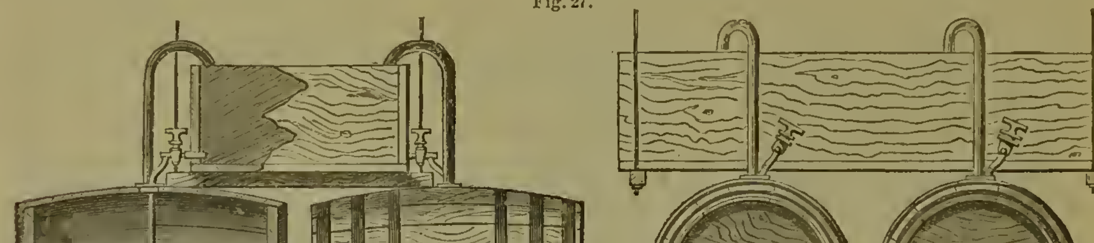


This system of cleansing may be extended (as shown in Fig. 28) by adding a tinned copper main, into which to screw the feed cocks, instead of putting them direct into the stillion. The main is supplied from a feed back at the end of the stillion, and the casks are kept filled up with bright beer instead of with beer from the yeast stillion. This brings the system to very nearly the same thing as union cleansing casks, but still at a greatly reduced cost, with the further advantage that ordinary casks are used. If the casks are used solely for this purpose, they can be brought still nearer to the arrangement of union cleansing casks by hanging them on crosses resting on a frame, as shown in Fig. 29.

This completes the ordinary process of brewing.

It often happens that the yeasty matter or grounds disseminated through the ale in the casks does not precipitate, and the consequence is that it causes the muddiness already noticed to remain. It appears that the composition of the water has a very great influence upon the cleansing of the ale, for when

Fig. 27.



lime compounds are present, the action of the salts inherent in the malt and dissolved in the worts causes a double decomposition, by which a lime salt is precipitated, and this carries with it the impurities to be removed. The Burton water is remarkable for its adaptation to brewing in this particular, namely, that no finings or other extraneous matters need be added to the fermented wort, in order to produce a clear transparent beverage.

With the exception of chloride of lime, bisulphite of lime, and quicklime, the less brewers have to do with chemicals the better.

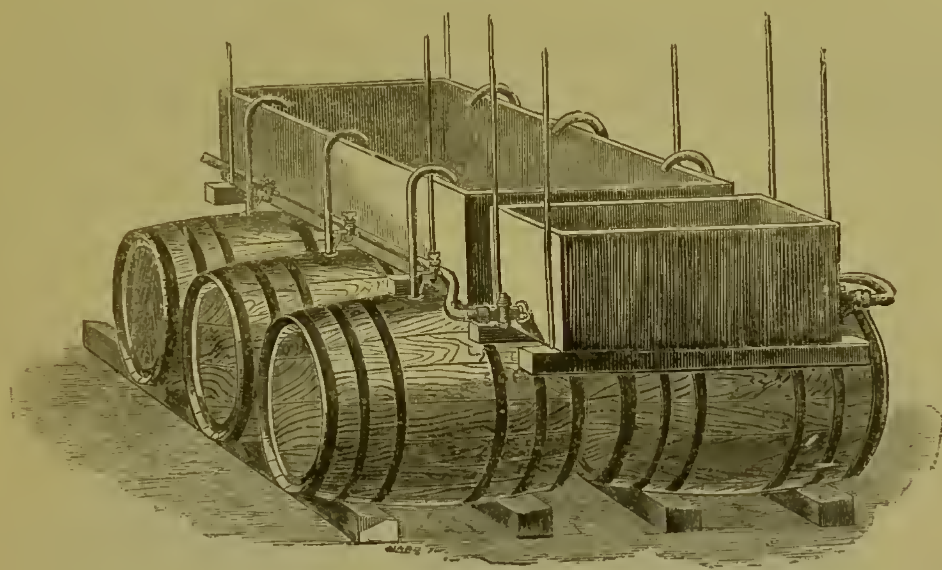
Simple quicklime, or some such alkali, mixed with the neutral or acid sulphite of lime, is useful when the beer turns hard, but it is far better not to produce hard sour ale.

In a great many instances, where recourse is had to the use of finings, a little more care bestowed upon the preceding operations would do away with the necessity of using them, and it is very question-

able whether. in any case, finings or precipitating agents for removing the impurities should be employed.

The substance most generally used for this purpose is isinglass, which is dissolved in sour beer, and then strained through a hair sieve. The consistence of the solution should be that of a pretty thick mucilage. When a small quantity of it is poured

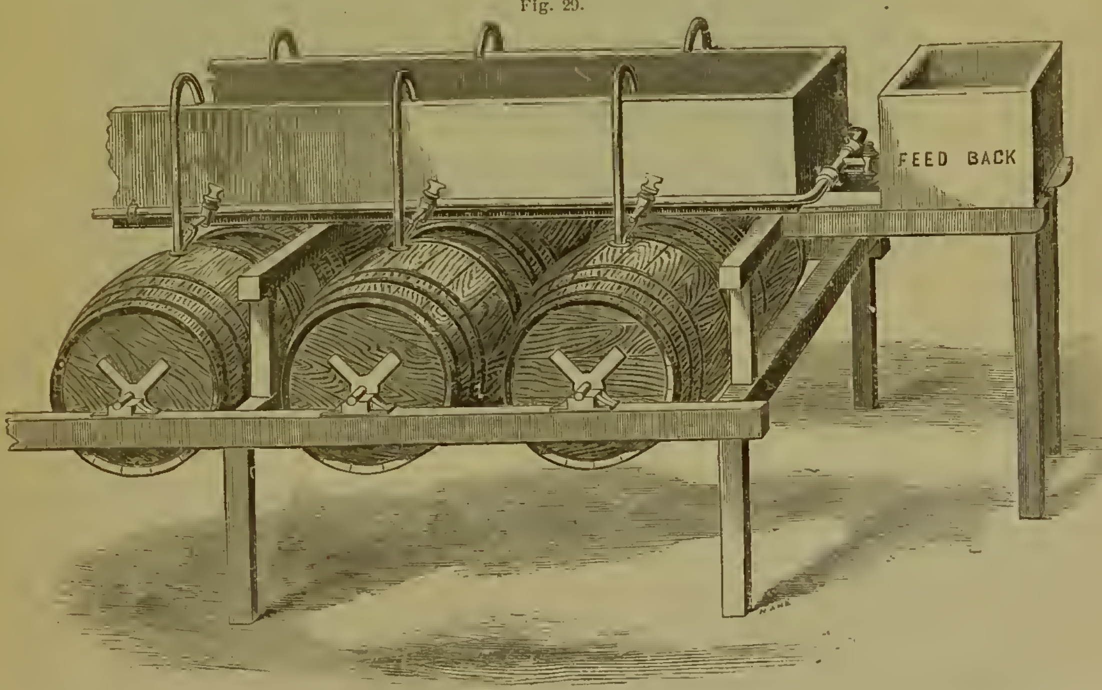
Fig. 28.



into a cask of the ale or beer, the grounds separate in a very short time, and the liquor remains bright, and free from mechanical impurities. One pound of isinglass will make twelve gallons of finings.

With respect to the action of the fining liquor on the ale, no very satisfactory explanation can be given. Many regard it as spreading over the surface of the liquor, and forming, as it were, a network, which, as it

Fig. 29.

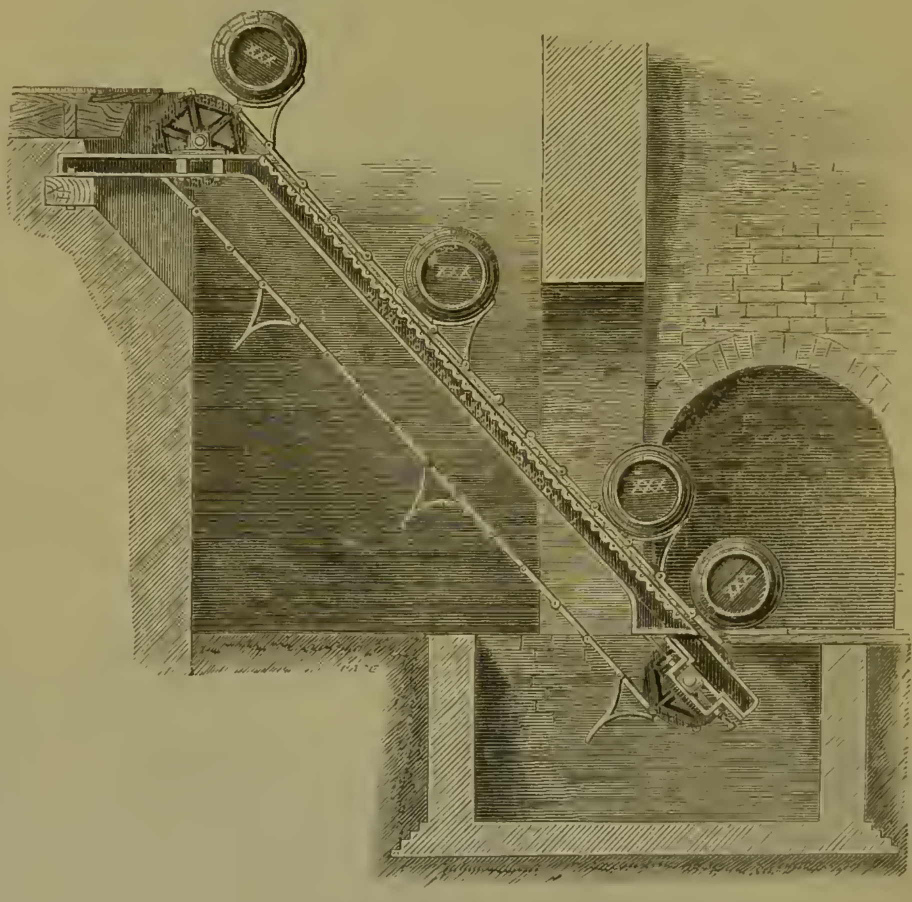


sinks, envelopes the whole of the mechanically suspended matters, and carries them with it to the bottom, while the supernatant liquor remains clear; others, again, look upon the floating impurity as being held by the cohesive attraction of the surrounding fluid in such a condition that, whilst the affinity of the latter is not so powerful as to cause solution, it is nevertheless so strong as to keep it suspended or in

combination; and the fining is supposed to operate by rendering the affinity of the solution for the grounds less, in consequence of being itself dissolved, while it is affirmed that the least derangement of this power is sufficient to insure their subsidence; while some think that, from the fining being lighter, it immediately ascends, carrying with it the deteriorating ingredient, leaving the beer in a clear state. It is evident, however, that there must be a combination of the yeasty matter with the isinglass (whether of a mechanical or chemical nature is not ascertained). This is more obvious from the circumstance, that other substances, such as glue, which seemingly partake of the same properties, will not effect this purification. It would seem also, that the great divisibility of the matter in the beer, together with a more or less cohesive affinity of the liquid for it, is the cause of its retention; and if this cohesion be in some measure destroyed, by either precipitating the substance, or bringing the particles closer together so that they may combine from the effect of the attraction among themselves, the liquid will then readily clarify. If when the isinglass solution is added no precipitate occurs, it may be made to take place by adding a little infusion of hops.

Many other bodies, such as albumen of eggs, or serum of blood, react on muddy ale like isinglass. DUNOVAN states that alum, in the proportion of one

Fig 30.



ounce to the hogshead, will purify it thoroughly in a very short time, and without leaving any perceptible taste; he further says that the dried stomach of the cod-fish, called "sounds," on being macerated in sour beer, affords a fining liquid equal in most respects to the more expensive isinglass. Eight or ten days are required to dissolve the sounds perfectly, when nothing remains but a small quantity of impurities, which straining through a cloth filter will remove. More or less of this solution is required, according to the purity of the liquor; but it is certain that, *ceteris paribus*, the less either of this or of isinglass liquid that is used the better, for these substances tend to communicate a flat taste to the beer, and prevent it from carrying a good head. When sounds are used, it is better to employ them in summer than in winter; in the latter season isinglass is to be preferred.

Very many persons, after the fermentation has ceased, instead of cleansing in the way above mentioned, add a fresh quantity of hops, and leave them in contact with the liquor till the whole of the yeasty substance is carried down with them as they subside. The ale, in this case, is improved to some extent by the addition of the fresh hops; but where the custom is to introduce some of the spent hops from a

previous operation, the practice is productive of more injury than benefit.

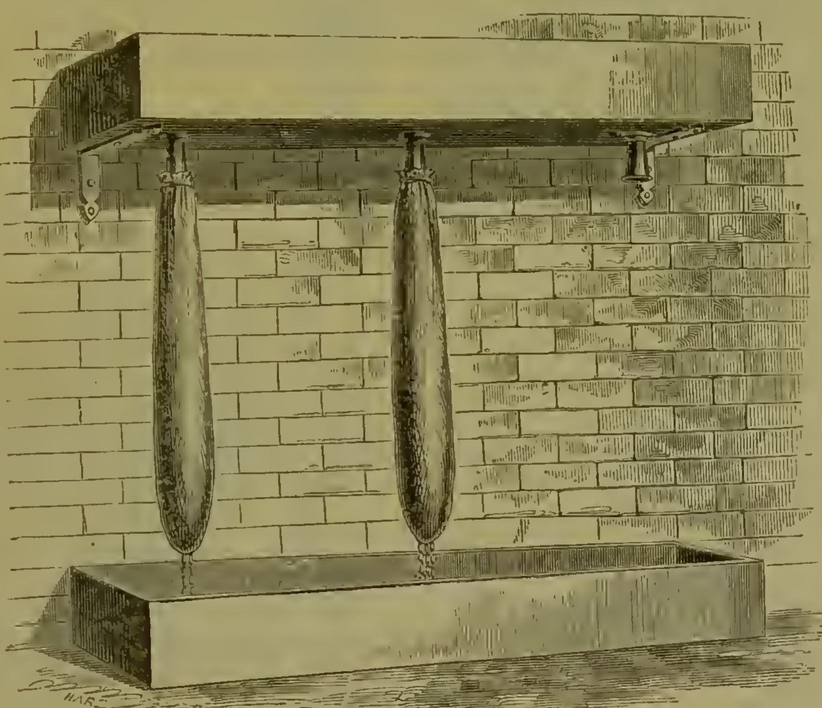
After the clarification, the ale is racked off into store vats, or barrels, to be sent to the consumers; and in doing so much attention must be directed to the casks and vessels, observing carefully that they are wholly free from any bad taste, smell, or putrid matter, which would contaminate the ale.

Beer is stored by preference in underground cellars for the sake of securing a cool temperature; and in many cases a cask-lowering machine is used for lowering the beer into the cellar. The best form consists of a platform working against a plate attached to the wall. The platform is suspended by means of counterpoise weights. When the platform is up, it is level with the floor from which the casks are to be taken. When the casks are rolled on to the platform, their weight causes it to descend, and when it reaches the floor of the cellar it strikes on a spring which jerks the casks off, and the counterpoise weights immediately bring the platform up to its original position.

To bring the beer up from the cellar it is customary to use a cask-raising machine (Fig. 30). This commonly consists of two strong wrought-iron endless chains, furnished with arms, running over pulleys driven by steam power, which pass through slots cut in the floor, and pick up the casks rolled to the foot of the elevator at the bottom of the cellar, and deliver them at the required height.

Some twenty years ago yeast was considered as almost refuse, but more recently brewers have become aware that it may be profitably utilized. This cannot be done unless the beer mixed with the yeast be separated from it, and the yeast rendered very nearly dry. Several machines for pressing yeast have been designed; the most successful are those patented by Messrs. NEEDHAM & KITE and Mr. G. A. WALLER.

Fig. 31.

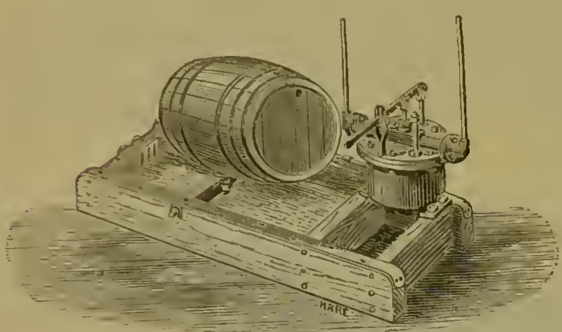


A simple but very efficient apparatus for filtering all kinds of thick beer and yeast is shown in Fig. 31. It consists of an upper trough, into which the yeast or other matter to be filtered is put. Into this trough one or more brass nozzles are screwed. To each nozzle is attached, by a brass ring, two bags, one within the other, the inner bag being the filtering medium. The inner bag is folded three or four times. The outer bag is only about half the diameter of the inner one; therefore as the yeast runs into the inner bag, it is swelled out and pressed against the outer bag. The inner bag is of course sewed up at the bottom, but the outer one is not completely closed up, and the filtered beer percolates through the bag into the trough below. As this apparatus is very inexpensive and requires no attention while at work, it is especially suitable for small breweries. When the beer ceases to run from the bag, the brass nozzle is unscrewed from the trough, and the bags taken off and washed.

In 1875 THOMAS ELLIS patented a process for the purification and preservation of yeast, which bids fair to make yeast a really valuable commodity to brewers. By his process the bitter is extracted from the yeast, and the yeast is granulated to a perfectly dry state, and will retain its fermentative powers unimpaired for years. It is evident that this process must be of very great value, since it will enable yeast to be exported and used for a variety of purposes for which it has been hitherto unavailable.

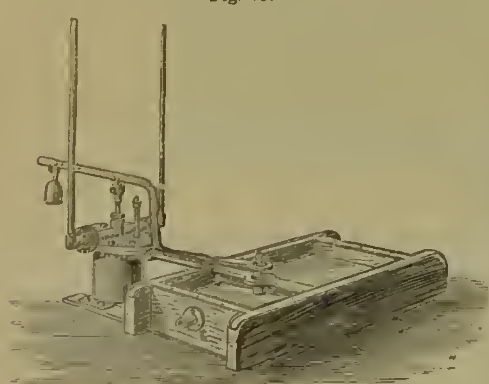
It is most essential that the casks in which beer is stored or sent out should be perfectly clean, and brewers are usually very particular on this point. Several methods of washing casks are used. The old plan is to about one-third fill the cask with hot liquor, bung it up, and roll it about for several minutes. Sometimes an iron chain is inserted into the cask at the bunghole; this scrapes off some of the dirt when the cask is agitated, but it is a tedious and laborious operation.

Fig. 32.



An apparatus, patented by Messrs. C. & F. PONTIFEX in 1871, not only cleans the casks in a thoroughly efficient manner, but also effects a great saving in labour, and in the quantity of hot water used. It is shown in Fig. 32. The cask cleaner consists of an iron feed-box (which holds the exact quantity of water required to wash the cask), connected by a pipe to a nozzle fixed across a trough or stillion. Steam and hot water are supplied to the feed-box, which has three gun-metal valves in it, one for the hot water, another for the inlet of steam, and a third

Fig. 33.



attached to the exit pipe to the nozzle; these are all worked simultaneously by the lever on the top of the box. When the apparatus is at rest, the water valve is open, and the steam valve and the exit valve are closed; the hot water, therefore, runs into the feed-box and fills it. The cask to be washed is then placed upon the nozzle, which is perforated with several holes, and is large enough to project through the bunghole of the cask. The lever on the feed-box is then raised; thus shutting the inlet water valve, and opening the steam valve and the exit valve. The pressure of the steam, which is taken direct from the steam boiler, forces the water from the feed-box through the exit pipe and nozzle into the cask. When all the water has been delivered, the steam blows into the cask through the water and completes the washing. By pressing down the lever the steam is then shut off, the delivery to the nozzle is closed, and the water inlet is opened, upon which the feed-box again fills with water, while the cask just washed is taken off and another one put on the nozzle. From 60 to 100 casks per hour may be thoroughly washed by one of these machines.

This machine is sometimes fitted with a self-acting arrangement, by which the weight of the cask sets the apparatus in action, and removing the cask

Fig 34.

shuts off the steam, and causes the box to fill with water ready for the next cask, as described above. The self-acting arrangement is effected as follows:—The feed-box is placed at the back of the stillion or trough (Fig. 33), and the lever for working the valves is brought to the nozzle on which the cask is placed; therefore, when the cask is placed on the nozzle it presses down the lever, and puts the apparatus in action, as described. This apparatus is extensively used and highly successful.

When casks are very foul from having been long empty, more thorough means are necessary for washing them. Sometimes the casks are unheaded and scrubbed out. Several machines for washing such casks have been designed: two well-known and successful ones may be here described. Fig. 34 shows a

machine with an iron frame revolving on trunnions, supported on legs. Motion is given to this frame by a chain and pulleys driven from a shaft above. Inside the frame is an iron cradle of a size to suit the cask to be washed. Into this the cask is placed and secured by a chain. This cradle has also trunnions which work in the iron frame first mentioned. On one trunnion is a wheel, which works into a worm fixed on the outside of the iron frame. On the end of the worm shaft is a counterpoise weight, shown in the lower part of the illustration. As the frame revolves, the weight of the counterpoise weight gives at each revolution one turn in the opposite direction to the cradle that carries the cask.

A good example of a modern brewery is shown in BEER, Plate I. It is a longitudinal section of a brewery erected in 1874 for Messrs. SEDGWICK of Watford, and designed by Messrs. HENRY PONTIFEX & SONS, of King's Cross, London, who also constructed the plant and machinery. In this brewery the wort is boiled by fire, and the liquor heated by steam. By aid of the following description the general arrangements will be readily understood:—

The liquor is raised from a well by one of the sets of pumps shown in the engine-room, and forced into the cold liquor tank at the top of the brewery. The malt is raised by a sack tackle into the malt store; thence it runs through a malt hopper into the malt rolls in the mill-room, and when crushed it is raised by an elevator to the upper part of the building, and delivered into either of the grist cases shown over the mash tuns. The cold liquor runs from the cold liquor tank into the hot liquor backs, where it is raised to the necessary temperature by steam coils. To each grist case is fitted a STEEL'S mashing machine, through which the grist and liquor are delivered into the mash tuns. Each mash tun is furnished with an internal machine fitted with COURON'S patent mashing rakes. The wort runs off to the copper underback, which has a steam coil in it to keep up the temperature of the wort, and thence runs into the wort coppers, where it is boiled. After the hops are strained from the wort in the hop backs, it is pumped by the other set of pumps in the engine-room into the cooler at the top of the building. From the cooler the wort runs to a set of LAWRENCE'S patent refrigerators, which stand on the mash-tun stage. By passing through this apparatus it becomes properly cooled, and flows into the fermenting tuns, which are furnished with skimming apparatus and attemperators. After fermentation, the beer is run into casks in the tun-room, where the fermentation or cleansing is completed. From the tun-room, the beer barrels are lowered to the cellar beneath by the cask-lowering machine, and when required to be sent out are raised by the cask-raising machine. Two steam boilers in the copper house supply the steam for driving the steam-engine, heating the liquor, washing casks, &c.

This brewery, with the two mash-tuns, is capable of mashing about 100 quarters of malt at each operation.

Having thus far given a general view of brewing, and the various causes which affect its success, a few words will now be added on the preparation of particular beverages, and first among these will be noticed—

PALE ALE.—Pale or East India ale is nothing more than beer made from worts extracted from the palest malt, and boiled with the palest and best hops. Every attention is given to the selection of these materials, in order to insure the pale colour peculiar to this ale. A great deal of East India pale ale is now used at home, but it differs from that exported, inasmuch as it is less bitter and more spirituous; in every other particular of manufacture and composition they are alike.

The only localities where this excellent beverage is produced in large quantities are Burton, London, Glasgow, and Leeds.

The peculiar excellence of these ales is their remarkable keeping quality, and their retention of that delicate flavour of the hops which is so often lost in ordinary brewing, notwithstanding the utmost efforts being made to secure it.

Success in brewing pale ale depends on the temperature of the fermentation being kept low, since this alone can preserve the beer from the simultaneous formation of acetic acid with the alcohol: 72° Fahr. (22°·2 C.) is the highest degree of heat that can be safely depended upon.

Brewing, it is well known, has been long carried on in Bavaria on these principles; but for a long time there was great objection to their adoption by the more extensive firms of this country, on account of the great length of time required for perfect attenuation. This difficulty, however, has at length been overcome, the fermentations being now finished in as short a time as by the old mode.

The modes of mashing, boiling, cooling, &c., pursued in different pale ale establishments are the same as those already explained, and therefore a recapitulation is unnecessary.

The only particular which requires to be noted, in addition to what has been already said, relates to the use of the hops, which are added in larger quantity than for the manufacture of the common ales.

ROBERTS states that the proportion of hops varies from 20 to 22 lbs. per quarter of malt; but, considering that the density of the worts is not so high as in many other instances, being about 1·055 specific gravity or upwards, the above proportion must in the majority of cases be very considerably more than the brewers of the present day employ. About 16 lbs. per quarter may be taken as the average allowance, though more or less within certain limits may be used—according to the special object of the brewer—in making a richer beverage, or inoculating the ale with a larger proportion of the bitter ingredient. Considerable care is exercised by the pale ale manufacturers in having the worts well boiled with the very best hops, so that all the valuable constituents of the flowers may be taken up in the gyle; hence it is not unfrequent among the Burton brewers to continue the boiling

for a period of two hours and a half or three hours. The cooling and pitching heat of the gyle are the same as have been described; and the fermentation and subsequent cleaning have also been fully explained. As, however, the routine and materials employed affect the fermentation, it may be well to offer a few observations upon this subject.

In making pale ales the fermentation should be restricted within the range of 60° to 68° or 72° Fahr. (15°·5, 20°, to 22°·2 C.), according to the degree of heat at the pitching, and the state of the weather. From the beginning of the attenuation till about three-fourths of the sugar are converted into alcohol, nothing further is required than to observe that the heat is gradually progressing in proportion to the attenuation. After this greater vigilance must be observed in skimming off the yeast and checking the action of the ferment, so that the further decomposition of the remaining portion of the sugar may take place at a declining temperature, during which the cleansing can be thoroughly executed.

When this is finished, and the clarified liquor is racked off, it is customary to allow it to rest for eighteen or twenty hours, in order that it may become more clear. It is then run into the casks, barrels, or hogsheads, as the case may be, which, when filled up to the bung, are shived or bunged tightly, and conveyed to the stores or consumers.

It is of great importance that the ale should commence a slow progressive fermentation in the cask, to retain its sparkling and brisk qualities; and to insure this, so much saccharine matter must be left in the liquor as will, by its conversion into alcohol and carbonic acid, communicate and keep up the requisite briskness; otherwise, if all the sugar were fermented in the first instance, and nothing left to develop the carbonic acid afterwards, the beer would be characterized as flat; while, if it retained nitrogenous matters and were conveyed to hot climates, it would in a short time become acid and putrefy.

Much of the success of the pale ale manufacture depends upon the care that is taken in selecting the best materials for its composition. It must also be understood that the several operations through which the malt and hops have to pass, as described in the preceding pages, must be performed with great attention, so as to preserve the colour, taste, and other properties of the ale in their fulness and purity.

Scotch Ales.—These ales at one time possessed a peculiar sweetness not to be found in other kinds of beer. This (especially as regards the Alloa ales) was owing to the addition of Russian honey to the liquor, a practice which has now been abandoned for many years. It is customary with the Scotch brewers to distinguish the quality of their ales by the price; thus, there are three guinea, four guinea, six guinea, and so on to ten and twelve guinea ales, but the latter are rarely brewed. The routine of mashing is much the same in Scotland as that usually followed by English brewers. The principal points of difference will appear from the annexed particulars gleaned from one of the most extensive brewers in Scotland.

The density of the wort depends, of course, upon the quality of the ale to be produced. The following are the densities adapted to the different qualities, reckoning by Allan's saccharometer:—

For 3 guinea	ale	the density is about	......	65°
" 4	"	"	......	80°
" 5	"	"	......	95°
" 6	"	"	......	108°
" 8	"	"	......	115°
" 10	"	"	......	125°

In preparing the worts of four guinea ale, two barrels of water at 175° Fahr. (79°·4 C.) are generally taken per quarter of malt and mashed; this is then sparged over with two and a half barrels of water at 190° Fahr. (87°·7 C.). For the other qualities of ale the same amount of water is taken for the mash, but the quantity used in the sparging is less in proportion to the density which the product has to indicate; thus, for five guinea ale the sparging is made with two barrels, and with one and a half for six guinea ale, whilst the spargings are not added at all in preparing the richer ales. Properly speaking, only one wort is drawn in Scotland, but the lengths of sparging, as just shown, make up for the after worts of the English brewer.

The hopping and boiling of the worts likewise vary but little from the practice already pointed out:—

4 to 5 lbs.	of hops	per quarter	are used for	4	guinea ale.
5 " 6	"	"	"	5	"
6 " 7	"	"	"	6	"

and so on. The period of boiling is from one to one hour and a half with the better class of ales, but is prolonged to two hours or longer when the product is poor. The criterion in this, as well as in those instances already alluded to, is the breaking of the flocculent matter, which the attendant carefully watches, and tests occasionally by taking samples in a small vessel and observing if the flocks readily precipitate. The cooling is performed in the usual way. The pitching heat is about 57° Fahr. (13°·8 C.), though sometimes it is reduced to 56° or even 54° Fahr. (12°·2 and 13°·3 C.). The period of attenuation extends from eight to twelve days, according to the weather, during which the heat rises to about 70° Fahr. (21°·1 C.) or more, but never higher if possible than 72° Fahr. (22°·2 C.). The extent of the attenuation varies from half to two-thirds of the original gravity. The cleansing of Scotch ales differs in no important particular from the usual system. It may be stated, however, that in Scotland the attenuation is finished in the fermenting tun.

The practice of adding flavourings in the shape of berries, &c., is now entirely discontinued in Scotland, at least among the more respectable brewers.

PORTER.—Previous to the year 1730 the malt liquors principally drunk in London were ale, beer, and twopenny, and it was usual for the customers to call for half-and-half, that is, half ale and half beer; half ale and half twopenny; or half of beer and half

of twopenny. In course of time it also became the practice to ask for a pint or tankard of "three threads," signifying a third of ale, of beer, and of twopenny; and thus the publican had the trouble of going to three casks to get the mixture required. To avoid this, a brewer conceived the idea of making a liquor which should unite the flavours of the three; he did so, and called it "entire," and as it was a hearty beverage, it was very suitable for porters and other workpeople: hence the name, "porter."

The manufacture of this beverage constitutes a large and profitable branch of the brewing business, especially in the metropolitan cities. London and Dublin porter stand foremost in point of quality.

Considerable disparity of working exists in the various porter breweries throughout the kingdom, which arises from many circumstances, such as the taste of the consumers, the nature of the climate, and such like. In theory, however, the work differs little from the course laid down for brewing ale. Such variations as do exist will be briefly pointed out.

As in the case of pale ale, the great difference in porter from common ale is in the materials worked upon. The grist employed by the porter brewer is composed of various species of malt, mixed together in different proportions.

The annexed table gives a view of some of these mixtures:—

TABLE OF PORTER GRISTS.

No.	Black.	Brown.	Amber.	Pale.	Total.
1	9	0	0	91	100
2	6	34	0	60	100
3	2	30	10	58	100
4	3	25	15	57	100
5	4	24	24	48	100
6	5	0	95	0	100

Of these, preference is given to the last two, as being the fittest for preparing a good porter; in the others, the excess of black and brown malt occasions too much carbonaceous and useless matter in them, from which the porter acquires a disagreeable taste, as if liquorice and similar compounds were mixed with it.

The malt, on being subjected to a high temperature during the drying, undergoes a decomposition, by which the farinaceous portions are deprived of their natural properties, and converted into a more or less charred mucilaginous substance, according to the degree of heat communicated.

In the amber malt, although some slight carbonization has taken place, yet it is not so powerful as to prevent the saccharification of any considerable portions of the starch, and therefore, while the wort prepared from this is much more coloured than it would be if obtained from pale malt, the sacrifice of valuable matter is not very great. As, however, the colour given to the mash is not so dark as the consumers require, a sufficient quantity of black or patent malt is employed to communicate this shade. The amount of the patent malt varies according to the skill of the manager, and the quality of the remaining portion of the grist.

As in the preparation of pale ales, so in porter breweries, strict attention must be paid to the qualities of the materials.

In preparing the worts a stiff mash is made, and after an hour's maceration a further portion of water at a high temperature is added, making a total of about 3 barrels of water per quarter of grist. The whole is mashed for a short time after the second addition, and then the tun is covered till the time of racking, which generally happens in an hour or an hour and a half's time. The worts are pumped into the copper, and boiled and hopped in the usual way. The quantity of hops varies with the quality of the porter to be produced, and according as it is, or is not, intended for exportation: in this the manufacturer must be left to the exercise of his discretion. Among the porter brewers the proportion extends from 6 to 16 or 20 lbs. per quarter. The usual period of boiling is an hour and a half; the grist is in the meantime being further exhausted by the addition of more water, so that a second wort may be ready by the time the contents of the copper are turned into the hop-back.

The hops used in the first boil, and which are not entirely deprived of their virtue, are in many establishments returned to the copper with the second wort, the whole retained at the temperature of ebullition for two hours, and then discharged to the hop-back, from which the gyle flows off, and is cooled down afterwards previous to fermentation.

Before proceeding further it may be well to make a short allusion to the temperatures at which the mashings are performed. In consequence of the malt being in a slight degree carbonized or decomposed, the tendency to set or form a coagulum is not so great as when pale malt is macerated in the water, and therefore the temperature of the liquor may be to some extent higher than if pale malt were operated upon. The reverse of this was for a long time supposed to be the case. Nevertheless, when the large proportion of pale or amber malt is used, the brewers content themselves with the application of water at 160° or 165° Fahr. (71°·1 to 73°·8 C.) for the first mash; and in the second, liquor of a temperature of 170° to 180° Fahr. (76°·6 to 82°·2 C.). These heats are subject to a variation of 5° Fahr. (2°·7 C.), or more, according to the judgment of the manager and the composition of the grist.

Porter gyle, after being cooled, has usually a specific gravity of 1·052 to 1·081, varying with the intended price of the beer.

The fermentation of porter gyle should be vigorously carried on, till the attenuation has advanced to about two-thirds the original gravity; this will take place, according to circumstances, in from two to four days, the temperature rising from 10° to 15° (5°·5 to 8°·3 C.). As soon as it is observed that the heat remains stationary, the preparation for racking off the beer to the rounds or "pontos" for the purpose of cleansing is entered upon. Here the barm is discharged and collected in a proper recipient, either by the use of such an apparatus as that at BASS or ALLSOPP'S, noted on a previous occasion, or by the ordinary method. As soon as the sensible

fermentation has ended in the rounds, the beer is either pumped into large open receivers, where it deposits a considerable quantity of the "lies" or "grounds," or is sent to the store vats to be matured.

When the beer does not clarify spontaneously, isinglass is generally used as a fining agent.

The finings are (according to URE) prepared as follows:—The isinglass is cut into slender shreds and put into a tub with as much vinegar or hard beer as will cover it (in Germany sour wine is used), in order that it may swell and dissolve. In proportion as the solution proceeds, more beer must be poured upon it; but it need not be so acidulous as the first, because, when once well softened by the vinegar, it readily dissolves. The mixture should be frequently agitated with a bundle of rods, till it acquires the consistence of thin treacle, when it must be equalized still more by passing through a tammy-cloth or sieve. It may now be made up with beer to the proper measure of dilution.

The quantity generally used is from a pint to a quart per barrel, more or less, according to the foulness of the beer. But before putting it into the butt, it should be diffused through a considerable volume of the beer with a whisk, till a frothy head be raised upon it. In this state it is poured into the cask and briskly stirred about, after which the cask should be bunged down for at least twenty-four hours, when the liquor should be limpid.

Sometimes the beer will not be improved by this treatment; but this should be ascertained beforehand by drawing off some of the beer into a cylindrical jar or phial, and adding to it a little of the finings. After shaking and setting down the glass, it is to be observed whether the feculencies begin to collect in flocky parcels, which slowly subside, or whether the isinglass falls to the bottom without making any impression upon the beer. The latter is always the case when the fermentation is incomplete, or a secondary decomposition has begun.

In Germany the finings are added to the worts prior to fermentation, as soon as they are let into the setting-back or tun, and immediately after adding the yeast to it. They are administered by mixing them in a small tub with twice their volume of worts, raising the mixture into froth with a birch whisk, and then stirring it into the worts. The clarification becomes manifest in a few hours, and when the fermentation is completed the beer is as brilliant as can be wished.

Porter intended for keeping, or for shipment to warm climates, requires to be as free as possible from any dregs or yeasty matter, and to be well seasoned. Nothing will avail the brewer in this particular so much as using the best materials.

Good porter has generally the following characteristics:—It is perfectly bright, dark-coloured, brisk or well impregnated with carbonic acid, light, sufficiently bitter to the taste, and free from too much acidity.

According to the opinion of several in the trade, the Excise regulations, as at present existing, depress their operations very much, in consequence of the duty being levied upon the malt, on the assumption that it will yield four barrels of beer of 19·4 lbs. per barrel, or specific gravity 1·054.

Laying down 84 lbs. as the maximum yield of a quarter of porter grist, this amount cannot be far from the truth, and according to many brewers the produce is more frequently 80 lbs. than otherwise; indeed, considering the loss in boiling, hopping, and fermenting, it is evident that the forementioned produce cannot be fully obtained. No drawback is allowed by the Excise upon the difference of the quantity upon which duty is levied, and that actually obtained; hence it is very evident that the manufacturer suffers.

BAVARIAN BEER.—The great and distinguishing feature of Bavarian beers (which are slowly fermented), is, that they do not contract any acidity when exposed to the air, whilst the products of English, Scotch, and French brewings invariably become sour under such circumstances. In addition to this very characteristic mark of the soundness of Bavarian beers, they possess in a high degree all the other qualities by which good beer is known, and hence are held in high estimation.

These valuable qualities are owing to the perfect system of fermentation to which the worts are subjected—a system which in itself has solved one of the most beautiful theories connected with it. Allusion has been already made to the causes of acidity in the gyle when speaking of boiling, but the explanation of the Bavarian method of fermentation will afford a clearer illustration of the matter than that adverted to. In gyles, generally speaking, the proportion of gluten, with reference to its utility in producing yeast or assisting in the fermentation, is greater than that of the sugar to its requirements in the formation of spirit and giving *fulness* to the drink; and although much of this excess may be removed by the boiling, still, after the usual process of attenuation has been effected, as by the generality of brewers in this country, a very considerable quantity of glutinous substance remains dissolved, and it is this that exposes the liquors to so much danger of spoiling, whereas, if it were removed, no apprehension of decomposition need be entertained. The process of fermentation, as carried out in Bavaria, is simply such as will entirely remove this excess of nitrogenous matter in the worts, and leave a beer containing no other constituents than water, alcohol, sugar, and the conserving principle of the hop.

The course adopted is the following, as described by Dr. CHARLES GRAHAM:—

The Bavarian, or old Bavarian, method of decoction consists in boiling the worts along with the grains.

The malt, after it is properly ground, is thrown into cold water, and it is allowed, after being mashed, to remain in cold water for a period varying from one to three hours. After this process has gone on as long as the brewer may think necessary, hot water is added, in order to raise the temperature of the mash in the tun to about 95° to 100° Fahr.

(35° to 37°·7 C.). The infusion process is thus set up.

After standing a short time, the tap is opened, and grains, meal, water, and everything is run off, and that is pumped up into a boiler. The wort and grains, with the moderate quantity of water used, form together a thick mass, which the Germans call *dickmaisch*. This thick mass is then boiled vigorously for half an hour. After it has been boiled it is turned back again into the mash-tun, in order to raise the temperature to about 122° or 125° Fahr. (50° to 51°·6 C.). The infusion process then goes on again. After that a second thick mash is again pumped up into the boiler, and again boiled briskly for half an hour, and it is then again run into the mash-tun, and the temperature in this way is raised to 145° Fahr. (62°·7 C.). It is then allowed to stand quietly after a little mashing. Before the thick mash is run from the copper, the mash apparatus is set to work for about ten minutes previously. It is thus infused, and then, in the old Bavarian method, the third mash, or *lautermaisch*, is run off, that is to say, a tolerably clear one not mixed with grains. This is pumped into the copper and boiled. After it has boiled about half an hour it is run into the mash-tun, and the temperature raised to 165° or 170° Fahr. (73°·8 to 76°·6 C.).

Thus the temperature is first that of cold water, in the second stage it is raised up to about 100° Fahr. (37°·7 C.), in the third stage to about 140° Fahr. (60° C.), then in the fourth stage to from 165° to 167° Fahr. (73°·8 to 75° C.), and lastly, the process is allowed to go on for a period of one hour. In the old Bavarian method, after tapping, sparging was done with cold water. Of late years hot water has been used, in that particular imitating the Scotch or English method. There are modifications of this process. For instance, sometimes instead of running off in the third stage the *lautermaisch*, a third *dickmaisch* is run off, and no *lautermaisch* at all. In other cases, instead of two thick mashes, only one is used, having instead two thin mashes, and so on.

The points which are gained by this method of boiling the thick mash are the following. The activity of a large part of the diastase is destroyed so far as its converting energy is concerned; but there is still some left in the tun. Now diastase is able to convert about 2000 times its own weight, and the Bavarian brewer maintains that he leaves a sufficiency of diastase in his tun to carry on the process which he has in view.

The boiling process, while it destroys the diastase, which may be looked upon as a disadvantage, has, at any rate, this advantage, that it thoroughly breaks up the integuments of the malt, and in that way the starch is converted into a sort of starch-paste. When the wort is run back again into the mash-tun, it there meets with the diastase that has not been destroyed, and the starch-paste is then very rapidly converted into dextrine and sugar. In addition to that, it is generally maintained by Bavarian brewers that in this way a large amount of soluble albuminous matter is brought into their worts, and that this soluble matter has undergone in that way a process of cooking, and therefore their worts and beer are rounder. It is an undoubted fact, whether that be really the case or not, that while they are killing so much of their diastase, they naturally have a greater ratio of dextrine to the sugar, so that their worts are rich in dextrine and poor in sugar. When such worts are fermented less alcohol is produced, so that, finally, the difference may be summed up in this way, that the beer made from the worts mashed in this process are less alcoholic or stimulating, because they had originally less sugar, but that they are rounder or fuller in the mouth; and in addition it is supposed, on account of the long cooking the albuminous matter has undergone, that it tends to preserve the beer better.

The fermentation of the beer is carried out in the main upon what is called the "bottom fermentation" principle. The tuns are all placed underground, in order that the temperature may be kept equal, and in addition they are surrounded with large quantities of ice. Sometimes there is from 8000 to 10,000 tons of ice placed around the fermenting room. The object of this is to keep the temperature low, and it is always kept as low as 40° Fahr. (4°·4 C.). The Bavarian brewers are also particularly careful in their attention to the purity of air, and the air is removed from time to time with a view to get rid of the small spores that are given off from the yeast *torulæ*. They are no less careful to keep the walls thoroughly clean. The temperature at which the fermentation is set varies slightly, but not more than 3° Fahr. (1°·3 C.). The lowest is about 42°, and perhaps the highest 44° or 45° Fahr. (5°·5, 6°·6, and 7°·2 C.). Ales intended for quick consumption are sometimes pitched at about 48° Fahr. (8°·8 C.).

The "bottom" yeast which Bavarians employ is very much the same as the English "top" yeast; but the yeast-cell is slightly smaller, and as a rule is ovoid. The amount added depends on a number of circumstances, because the yeast varies in power. It generally varies from 7 or about 8 litres to 12 for every 4000 litres of wort used. It is applied, generally speaking, in the same manner as in this country, by simply mixing it with a little of the wort and then supplying that to the remainder. Another plan is to take a portion of the wort, add the yeast to it so as to start fermentation, and after it has gone on about twelve hours, adding it to the remaining wort. The object of doing this is that as little yeast as possible may be used.

The phenomena observed in a Bavarian fermenting tun (and their tuns are very much the same as those at Burton, simply a deep tun or barrel) are these:—After some twelve hours a little carbonic acid is formed. Of course that which is formed at first is absorbed, and as the temperature is very low, much more is absorbed than with us. In some twenty-four to thirty hours a scum appears, and then twelve to fifteen hours later there is thrown up to the surface a light yellow or brown yeast, containing the resinous matter of the hops, together with many of the dead cells. This is very carefully removed, for the purpose mainly of keeping the yeast

pure. The fermentation goes on after this much more slowly and regularly, and the carbonic acid is given off in very minute bubbles; hence therefore the cells do not rise to the surface, but sink to the bottom.

The process goes on for some ten, twelve, fourteen, or sixteen days, and in the case of very strong ale, at a very low temperature, as long as three weeks. But as a rule it lasts some twelve days, and the attenuation at the end of that time is carried to about the extent of one-half the original gravity. Having completed the action in the fermenting tun, the gyle is run into a large store barrel, and here the sugar and dextrine of the wort are gradually used up by the yeast cells and converted into carbonic acid.

The sugar of course breaks up readily enough into carbonic acid and alcohol, but dextrine is a much more inert body, and in the absence of sugar is with difficulty broken up. But, though dextrine does not by itself yield readily to the alcoholic decomposition, yet in the presence of grape sugar it does break up gradually into alcohol and carbonic acid.

On each large barrel or fermenting tun (they are not very large) is fixed a manometer or pressure gauge. The barometer is also found in each brewery, and of course the thermometer, and the brewer every day as he passes along notices, not merely the atmospheric pressure, but also the internal pressure in the store vats; because by so doing, he is enabled to decide whether the slow decomposition of the sugar and the consequent introduction of alcohol is going on steadily. As he passes down he looks at each small gauge, and notices by the scale the amount of internal pressure, which should always be equal to some few inches of water; and if he finds that the pressure of the internal carbonic acid is much less than it ought to be, he then feeds the yeast in such a barrel with sugar.

Thus in the Bavarian system, where the ale is kept for weeks and months, there is a gradual process of feeding going on. The German brewer carefully avoids oxidation by a slow system of feeding, little by little, and in that way he insures that there shall always be a pressure inside greater than the atmospheric pressure. While he notices the indication of the manometer, he bears in mind the atmospheric pressure outside, because it may occasionally happen that the barometer has fallen or risen some 2 or 3 inches, and of course therefore he guides his process, not only by looking at the barrel manometer, but also at the external atmospheric pressure.

There are, perhaps, no brewers in the world more careful to avoid exposure to the action of the air than the Bavarian brewers. In their store vats they allow a space of about a hand-breadth between the surface of the liquid and the bung itself, with a manometer indicating the difference between the internal and external pressure. And they are equally careful in the original fermenting process to have a layer or covering of carbonic acid over the fermenting wort.

But a process of oxidation is nevertheless going on, and the oxygen is derived from the liquor. Water is decomposed by the yeast organisms, and the oxygen of the water goes to oxidize the albuminous matters, but at that low temperature does not oxidize any of the alcohol; consequently, in the Bavarian system, less aldehyde is formed, and less acetic acid, and owing to the low temperature, but a very small quantity of lactic acid and acetic acid. So long as the beer *torulæ* are working, there is a guarantee that at that low temperature the acetic acid ferment (the *Micodermi aceti*), shall not be able to thrive, and also that the lactic acid ferments shall not thrive, because the conditions are unfavourable for their rapid growth. On the other hand, a low temperature is very favourable to the production of the yeast *torulæ*, and so long as these are growing fast and multiplying, even if the others come into the field, they are gradually driven out, because the climatic conditions are unfavourable to their rapid development. Hence, in the Bavarian system, the sugar is thoroughly and economically decomposed, and at the low temperature employed the major portion of the oxygen derived from the decomposition of the water goes to oxidize the glutinous matter of the wort. The temperature of the fermenting tun is kept down by the Bavarian brewers, but not in the same way as in this country. The plan used is very simple; large lumps of ice are thrown into the fermenting tun, or when that is not available, because it turns into water and makes the beer too weak, a small floating vessel is nearly filled with ice, and placed in the middle of it.

The beer produced in this way contains very often no more than 1½ to 2 per cent. of alcohol. It has a full-mouthed round flavour; and though the amount of hop used is very slight, yet it has a delicate aroma. The peculiar flavour which the Bavarian ale has is not in any way to be attributed to fermenting at low temperature, but is produced entirely by the very free use of pitch or resinous matters to protect the wood of the fermenting tun. The result is, that as alcohol is formed it dissolves some of the resinous matters, and gives the beer the taste which is so unpleasant to Englishmen.

As regards the fermentation generally, the salient features from a chemical point of view are, first of all, that the decomposition depends upon two factors, namely, temperature and pressure, and as they vary so do the products vary. High temperature—the barometrical pressure being the same—produces a rapid decomposition of the sugar in the wort, more hydrogen is evolved, more aldehyde is formed, and more acetic acid; at the same time less nitrogen is evolved, and on account of the favourable thermal conditions, there is also more lactic acid. Low temperature on the other hand, if the barometric pressure be the same, produces a slower action; but there is less hydrogen, and more nitrogen, and there is a more complete oxidation of the albuminous matter. This is important, because on the perfect separation of the glutinous matter depends the future store-keeping qualities of the ales. High barometric pressure may be considered very much the same in its effects as low temperature, and *vice versâ*; but the range of variation of the

barometer is never greater than some 3 inches, and consequently this is by no means so important a factor as the question of temperature. For store ales, fermentation ought to be carried on at a temperature intermediate at any rate between the Bavarian and the very high temperature that some of the British brewers use; and above all, the secondary fermentations should be carried out underground, under conditions of low and equable temperature, which ought not to be allowed to exceed 55° Fahr. (12°·7 C.).

LAMBICK BEER. *Faro beer; bière de mars.*—In this mode of brewing the wort is self-impregnated with the ferment. This process is practised to some extent in Dorsetshire. It is also carried out on a large scale in Belgium. The brewers mix barley malt with an unequal weight of unmalted wheat (wheat contains a large amount of gluten); the mashing is carried on by a modification of the Bavarian process, that is to say, they make a moderately cool mash, starting at a low initial temperature, and then by repeated boilings finally obtain a wort which, like the Bavarian wort, contains a large quantity of dextrine. The wort is then cooled, and is placed in a number of barrels, the bungholes of which are left open. The barrels being filled, the wort is left to mature.

Sometimes it is weeks before the fermentation appears, but sooner or later fermentation is started; occasionally, when it is very obstinate, they add a little unboiled wort to stimulate it, much in the same way that English brewers add a little malted barley for the purpose of stimulating sluggish fermentation. The fermentation goes on slowly for weeks or even months, and like the German system, it is generally of a bottom character; the bulk of the yeast falls to the bottom, though at the same time a portion is thrown out to the surface. After the fermentation has gone on for this long time, by degrees the beer becomes clear.

For Faro beer they boil their worts about six hours, and for Lambick, or *bière de mars*, they carry on the boiling process for twelve or fourteen hours. The ale thus produced is excessively hard, and contains a large quantity of lactic acid present, though when it has once cleared itself, the lactic acid seems to guard it against any future attack of these small organisms. When it is once made, and sometimes it takes from two to four years before the beer is fit to drink, it withstands any future oxidation remarkably well.

ADULTERATION OF BEERS.—This subject, fortunately, is not so difficult to deal with at the present day as it was about half a century ago. Whether this result is owing to the increased morality of the brewer, or to the vigorous measures taken by Government in detecting and punishing sophisticators, is a difficult point to determine; but certain it is, that the ingredients which are said to have been employed at that time are positively frightful to contemplate.

The cause of some of the adulteration might, with truth, be said to originate with the consumers, some fancying a pale liquor, whilst others preferred an amber or brown.

At one time the close approximation of the colour to black was imagined to be a sure sign of perfection.

To communicate such a shade, and at the same time evade the duty payable upon the malt, many resources were tried, such as the use of caramel or treacle boiled down to blackness, elder-berries, Spanish juice, &c., and these continued to be used for a considerable period. Caramel, or burnt sugar, and liquorice, are said to be employed at the present day. In the other departments of the manufacture, especially in the means employed for preventing acidity, raising of a creamy head, and giving a semblance of age to the product, many brewers have recourse to such substances as sulphate of iron, chalk, or the carbonates of alkaline earths.

When the beverage is made from good materials, and with proper care in the fermentation, it remains sufficiently viscid from the gummy matter and sugar in solution, so that in pouring it from one vessel to another it gathers on its surface a close creamy foam or head, which, when blown aside, readily closes again. This is more particularly the case with good porter; but when the body or unfermented matter of the beverage is in small or insufficient quantity this does not take place, and the bad quality of the liquor is thus detected by the consumer.

In order to conceal this inferiority and give an appearance of richness, the brewer sometimes, but the vendor very often, adds more or less of "heading stuff," made of isinglass and sour ale beaten well together, introducing a small quantity of this with an ounce or two of sulphate of iron into each hogshead. This has the effect of raising a froth upon the liquid, and also of making it to close immediately when blown aside.

By the use of chalk, beer which has become sour may be deprived of its acidity, but it will never be palatable after such treatment, especially if the quantity of acid in it is rather large.

When beer turns hard, especially in the porter establishments, the practice is to mix the sour with fresh-brewed beer, and send it to the consumers at once as old porter.

Many ingredients are said to be mixed with beer, particularly by retailers, to increase the stupefying properties of the liquor, and even the thirst of the consumer; but such adulterations have not come within the range of the Editor's experience. It is asserted, however, that many herbs and seeds, such as wormwood, India berry, or *cocculus indicus*, the fruit of the *Picrotoxia*, or *Menispermum cocculus* (a plant containing an active poisonous principle), *picrotoxin*, and various others, are employed to impart bitterness.

ANALYSIS OF BEER.—This is of much importance to the brewer and the public; to the first it is a means whereby he learns the composition of worts or gyle, and can modify his mode of working accordingly; to the second it is of great consequence, as it detects the often poisonous adulterations of malt liquor. It

is of importance also to the exporter to be able to analyse his beer, and from the results to deduce the original gravity of the wort; for by Act 10th Victoria, cap. 5, a drawback is granted of five shillings per barrel of 36 gallons upon beer exported, of which the worts used before fermentation are of not less specific gravity than 1·054, and not greater than 1·081; and a drawback of seven shillings and sixpence upon beer exported, the worts of which, before fermentation, were not under 1·081 specific gravity.

The constituents most necessary for the analyst to determine are, the alcohol, water, acetic acid, saccharine, glutinous, and bitter extractive matter of the malt and hops. A complete investigation of these is sometimes necessary for the purpose of detecting any foreign or destructive principle introduced as an adulterant.

Much may be learned from an attentive examination of the beer before it is analysed. It should be perfectly clear; turbidness shows that either the acetic or vinous fermentation is going on. The smell and taste of the hops, and the quantity of carbonic acid, which may be judged of from the creaminess of the head (unless head matter has been employed), afford to the connoisseur a means of judging of the quality of the ale with tolerable certainty.

For excisable purposes, the following is the method recommended for the analysis of beers, so as to find the original density of the wort. An accurately graduated four ounce bottle is provided and filled with the beer to be examined, after which the contents, together with the rinsings, are transferred to a retort to which a condenser is affixed, and the measured bottle is used as a receiver. Distillation is then continued till somewhat more than half the quantity of liquid is drawn over, so as to insure the elimination of the whole spirit. The remainder of the measured bottle is then filled with distilled water, and the specific gravity of the mixture taken at 60° Fahr. (15°·5 C.). If, instead of 1·000, the weight should indicate ·987, it shows that the weight of the diluted spirit is 13° less than the water; this is *the spirit indication of the beer.*

By referring to the tables drawn up for this purpose (see ALCOHOL), the density of the worts producing it will be ascertained. In this case it is 59·4. The residue in the retort must then be washed with a small quantity of distilled water into the four ounce bottle, which is then filled with water, and the gravity found as before, and its excess over that of water added to the preceding number, plus 1000, and the sum will be the original gravity of the wort. Thus—

If the spirit gravity be................	59·4
And the extract do....................	1030·0
Gravity of the worts,...............	1089·4

The annexed table, constructed by Professors GRAHAM, HOFMANN, and REDWOOD, is that by which the Excise are guided in most cases of this description. These numbers in the body of the table indicate the strength of wort corresponding to the spirit indication in the margin.

Degrees of spirit indication	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	0·0	0·3	0·6	0·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·9	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	59·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9
15	70·5									

WATTS gives the following method for ascertaining the amount of alcohol ("Dict. of Chemistry," vol. i. p. 530):—15 to 30 ounces (500 to 1000 grammes) are distilled in a somewhat capacious retort, having its neck inclined upwards and connected with a Liebig's condenser; the distillate is received in a tared flask, weighed, and its specific gravity determined at 60° Fahr. (15°·5 C.), that of water being assumed = 1·000; or the proportion of alcohol may be found by testing the distillate with a delicate alcoholometer. The weight per cent. of alcohol is thus found by means of Table A, and hence the total amount of alcohol in the given quantity of beer may be found.

Suppose, for instance, 1000 grammes of beer gave 615·38 grms. of distillate of specific gravity 0·98949 at 60° Fahr., then, according to the tables, the distillate would contain 37·6 grms. alcohol. Now these 37·6 grms. of alcohol were obtained from 1000 grms. of beer, consequently the amount of alcohol in the beer is 3·76 per cent. The trouble of calculation may be saved by diluting the distillate till its weight becomes equal to that of the beer employed; the specific gravity will then at once give the percentage by weight of alcohol in the beer. If, for example, the distillate after dilution exhibited a specific gravity = 0·9932, the percentage of alcohol would be 3·76. If a TRALLES alcoholometer were used it would show in the distillate, before dilution, a percentage by volume of 7·6, corresponding to 6·11 by weight. In using the alcoholometer it is best not to dilute the distillate, unless the instrument is specially graduated for very weak liquids. If the observed specific gravity, or alcoholometer degree, does not occur in the table, the weight per cent. of alcohol will be found by interpolation.

The residue in the retort may be used for determining the amount of extractive matter in the beer. For this purpose it is diluted with water, after cooling, till its weight becomes equal to that of the beer before distillation; and the amount of extractive matter is then found from its specific gravity by means of Table B.

A table by Dr. URE of the specific gravity of pure syrup, which does not differ very greatly from that of malt extract, is given at page 299.

TABLE A. SPECIFIC GRAVITY AND STRENGTH OF SPIRITS.

Volume per cent.	Weight per cent.	Specific Gravity.	Volume per cent.	Weight per cent.	Specific Gravity.
1·0	0·80	0·99850	4·6	3·68	0·99336
1·1	0·88	0·99835	4·7	3·76	0·99322
1·2	0·96	0·99820	4·8	3·84	0·99308
1·3	1·04	0·99805	4·9	3·92	0·99294
1·4	1·12	0·99790	5·0	4·00	0·99280
1·5	1·20	0·99775	5·1	4·08	0·99267
1·6	1·28	0·99760	5·2	4·16	0·99254
1·7	1·36	0·99745	5·3	4·24	0·99241
1·8	1·44	0·99730	5·4	4·32	0·99228
1·9	1·52	0·99715	5·5	4·40	0·99215
2·0	1·60	0·99700	5·6	4·48	0·99202
2·1	1·68	0·99686	5·7	4·56	0·99189
2·2	1·76	0·99672	5·8	4·64	0·99176
2·3	1·84	0·99658	5·9	4·72	0·99163
2·4	1·92	0·99644	6·0	4·81	0·99150
2·5	2·00	0·99630	6·1	4·89	0·99137
2·6	2·08	0·99616	6·2	4·97	0·99124
2·7	2·16	0·99602	6·3	5·05	0·99111
2·8	2·24	0·99588	6·4	5·13	0·99098
2·9	2·32	0·99574	6·5	5·21	0·99085
3·0	2·40	0·99560	6·6	5·30	0·99072
3·1	2·48	0·99546	6·7	5·38	0·99059
3·2	2·56	0·99532	6·8	5·46	0·99046
3·3	2·64	0·99518	6·9	5·54	0·99033
3·4	2·72	0·99504	7·0	5·62	0·99020
3·5	2·80	0·99490	7·1	5·70	0·99008
3·6	2·88	0·99476	7·2	5·78	0·98996
3·7	2·96	0·99462	7·3	5·86	0·98984
3·8	3·04	0·99448	7·4	5·94	0·98972
3·9	3·12	0·99434	7·5	6·02	0·98960
4·0	3·20	0·99420	7·6	6·11	0·98949
4·1	3·28	0·99406	7·7	6·19	0·98936
4·2	3·36	0·99392	7·8	6·27	0·98924
4·3	3·44	0·99378	7·9	6·35	0·98912
4·4	3·52	0·99364	8·0	6·43	0·98900
4·5	3·60	0·99350			

TABLE B. SPECIFIC GRAVITY AND STRENGTH OF MALT EXTRACT.

Specific Gravity.	Malt Extract in 100 parts of Liquid.	Specific Gravity.	Malt Extract in 100 parts of Liquid.
1·000	0·000	1·036	8·925
1·001	0·250	1·037	9·170
1·002	0·500	1·038	9·413
1·003	0·750	1·039	9·657
1·004	1·000	1·040	9·901
1·005	1·250	1·041	10·142
1·006	1·500	1·042	10·381
1·007	1·750	1·043	10·619
1·008	2·000	1·044	10·857
1·009	2·250	1·045	11·095
1·010	2.500	1·046	11·333
1·011	2·750	1·047	11·595
1·012	3·000	1·048	11·809
1·013	3·250	1·049	12·047
1·014	3·500	1·050	12·285
1·015	3·750	1·051	12·523
1·016	4·000	1·052	12·761
1·017	4·250	1·053	13·000
1·018	4·500	1·054	13·238
1·019	4·750	1·055	13·476
1·020	5·000	1·056	13·714
1·021	5·250	1·057	13·952
1·022	5·500	1·058	14·190
1·023	5·750	1·059	14·428
1·024	6·000	1·060	14·666
1·025	6·241	1·061	14·904
1·026	6·488	1·062	15·139
1·027	6·731	1·063	15·371
1·028	6·975	1·064	15·604
1·029	7·219	1·065	15·837
1·030	7·463	1·066	16·070
1·031	7·706	1·067	16·302
1·032	7·950	1·068	16·534
1·033	8·195	1·069	16·767
1·034	8·438	1·070	17·000
1·035	8·681		

The amount of alcohol in beer may in most cases be calculated with sufficient accuracy for practical purposes, from the difference in the specific gravity of the boiled and unboiled beer, according to the following principle:—The specific gravity of the unboiled beer is less than that of the boiled beer, in the same proportion as the specific gravity of spirit of wine of equal alcoholic strength is less than that of water.

To determine the amount of alcohol in beer accordingly, the beer is first freed from carbonic acid by brisk agitation in a capacious flask, assisted perhaps by very gentle heating, and its specific gravity accurately determined. It is then boiled to drive off the alcohol, and the residue is diluted with water, till its weight becomes exactly equal to the original weight of the beer; it is next filtered, if necessary, through a covered filter, and its specific gravity likewise determined. The amount of alcohol is then calculated, as in the following example:—

Suppose the specific gravity of the unboiled beer free from carbonic acid to be 1·0280, and after boiling and dilution with water, to be increased to 1·0320: then, according to the principle just stated, the specific gravity of pure spirit of the same alcoholic strength as the beer, will be to that of water as 1·0320 : 1·0250; that is to say, it will be $\frac{1·0250}{1·0320} = 0·9932$, which, according to Table A, corresponds to 3·76 per cent.

The empirical rule for finding the specific gravity of spirit of equal strength with the beer is:—Divide the specific gravity of the unboiled beer by that of the boiled beer, after its original weight has been restored by dilution.

It is clear that the results obtained by this method (called in Germany the "Specific Beer-test"), will be more exact in proportion as the composition of the beer differs less from that of pure spirit of equal strength; in other words, the smaller the amount of the extractive matter contained in the beer.

The quantity of extractive matter in beer may be determined by evaporating a known quantity of beer in a platinum or porcelain dish, and drying the residue in an air bath at 212° to 239° Fahr. (100°-115° C.), till it loses weight. Before weighing it must be cooled under a bell jar, over chloride of calcium, as it is very hygroscopic.

It is seldom necessary to examine the extractive matter any further. It consists mainly of sugar, dextrin, albuminous matter, and lupulin (the bitter principle of the hop.)

The amount of dextrin and sugar may be determined by moistening the dried residue with water to a thin syrup, and gradually adding strong alcohol as long as dextrin is thereby separated. The clear sugar solution may then be decanted, and the dextrin freed from the remaining sugar by repeated solution in water and precipitation by alcohol. The solution of dextrin and sugar may then be evaporated to dryness and the residue weighed. The albuminous matter may be estimated from a separate portion of the beer by boiling it so as to coagulate the albumen, collecting the precipitate in a tared

filter, then washing, drying, and weighing it. Lastly, the sum of the weights of the dextrin, sugar, and albuminous matter, deducted from the total weight of the extract, gives the quantity of lupulin.

Another simple process is as follows:—The beer is well agitated to free it from the carbonic acid which it contains, and then a certain weight is taken and introduced into a retort connected with a condenser and receiver, and the whole of the spirituous liquor drawn off and tested. (See ALCOHOL.) The residuary matter remaining in the retort, after the most part of the fluid has been distilled off as just stated, is to be mixed with as much distilled water as will make up the same bulk of liquid as was originally employed, and the specific gravity of this liquid is to be taken by an accurate hydrometer. By this means the quantity of alcohol and extractive matter in the beer is found. To determine the amount of sugar in the solid matter of the beer, a portion of the liquor is weighed and introduced into a flask or beaker, and boiled; if a coagulum should form, it is to be collected upon a dry tared filter, then washed, dried, and weighed. The liquor is next evaporated till it becomes thick; strong spirit of wine or concentrated alcohol is then added, causing a precipitate of the gum and mucilaginous matter, which is collected and washed with spirit till all the sugar is extracted; it is finally dried and weighed, and its quantity noted. By evaporating the alcoholic filtrate to remove the spirit, dissolving the residue in water, and boiling the liquid with a grape sugar test solution, made by dissolving—

100 grains of crystallized sulphate of copper,
200 grains of bitartrate of potassa,
800 grains of crystallized carbonate of soda,

in 8750 grains, or one pint of boiling distilled water, and filtering if necessary, a precipitate of suboxide of copper falls, which, when collected, dried, and weighed, affords an indirect but accurate method for ascertaining the amount of saccharine matter, since every 3 grains of the suboxide indicate 1 of grape sugar. Having thus ascertained the percentage of albumen, if any, as also of gum and sugar, then, by deducting their total from the quantity of fixed residue, the difference will be the percentage of lupulin, or extractive matter of the hop.

If the beer was adulterated with any of the bitter substances before mentioned, they will remain in company with the lupulin.

The quantity of acetic and lactic acid in beer is determined by weighing or measuring a certain portion, and neutralizing it with a standard solution of pure carbonate of soda or of ammonia, added gradually from a burette, and calculating the percentage of those acids from the quantity of the test liquor employed. If lactic acid be suspected, another weighed portion of the liquid should be evaporated to dryness, the residue affused with water, and neutralized by the forementioned solution. From the number of measures required, the quantity of lactic acid is calculated. The equivalent of dry lactic acid is 90. By deducting the amount of lactic from the total weight of acid, as above ascertained, the remainder will be acetic acid.

Carbonic acid gas may be determined either by boiling a quantity, say a quart of the beer, and collecting the gas in a pneumatic apparatus, or if this be not convenient, transmitting it into a solution of baryta or lime, and collecting, drying, and weighing the precipitate which it occasions. If lime-water be employed, every 50 parts of the precipitate will denote 22 of carbonic acid.

If inorganic adulterations be suspected, their presence may be proved by evaporating the beer to dryness, and incinerating the residue in a platinum capsule or basin, till the whole of the organic matter is dispelled, then dissolving the ash or fixed matter in hydrochloric acid, and testing—for iron, with sulphocyanide of potassium, which will give a blood-red coloration if it be present; for lime, by the addition of ammonia and oxalate of ammonia, which will cause a white precipitate. Common salt is almost always present; it may be estimated by dissolving a portion of the residue, after incineration, in water, filtering, and adding nitric acid and nitrate of silver to the liquid; from the weight of the precipitated chloride of silver the amount of salt is calculated. Should alum be present, it will precipitate in the form of white flocculi, on adding ammonia to the solution when testing for lime.

If copperas (ferrous sulphate) has been added to promote the heading, the liquid will give the reaction of sulphuric acid with chloride of barium, and the ash will contain an abnormal amount of oxide of iron.

J. L. LASSAIGNE, during his researches upon picric acid, discovered a distinctive difference between the bitter principle of the hop and this acid. He says that some time back this acid was used as a partial substitute for hops, and that the practice was carried on to a considerable extent in certain districts in France. With the view of finding a ready means for detecting this adulterant in beers, he undertook the investigation. He observed that the taste cannot distinguish between the bitterness of picric acid and the lupulin of the hop; but that, by having recourse to the following experiments, the presence or absence of the adulterant may be readily ascertained. The beer is to be agitated with a solution of subacetate of lead in excess; this throws down a precipitate, consisting of the bitter and most of the colouring matter of the hop, whilst picric acid, if present, is unaffected by this reagent, and therefore remains, communicating its peculiar taste to the liquid. Another test, LASSAIGNE remarks, is this, that common bone charcoal, purified by acids, will precipitate and retain the colouring matter of the beer; but that picric acid passes through this medium, communicating its natural canary yellow tint to the filtrate. Upon these applications he bases the method of recognizing very minute traces of the acid when added to beer.

In his experiments to prove the efficacy of the test, he operated upon equal portions of a well-made beer, to one part of which one-twelve or one-eighteen thousandth of the adulterant was added. On pouring into these samples subacetate of lead in excess, or

on shaking them with powdered animal charcoal, the pure beer is almost entirely decolorized, whilst the adulterated sample retains its yellow citron colour. Exceedingly minute traces of the adulteration may be detected by evaporating the liquid, and when reduced to a half or quarter of its bulk, applying the tests.

According to POHL the most delicate test for picric acid is its behaviour towards unbleached wool. A flock of sheep's wool, or any fabric made thereof, is immersed in the beer to be examined, and the whole boiled for ten minutes, it is then removed and thoroughly washed to remove the wort. If the beer is free from picric acid the wool remains white, but if only so much as one part of picric acid in 125,000 parts of beer is present, the wool becomes of a canary yellow colour, which is more or less strong according to the quantity.

It has been observed by BRUNNER that the dyeing of the wool is rendered easier and more certain by the application of a moderate heat (that of the water bath), and by previously acidulating the beer with hydrochloric acid. It must be observed, however, that besides the picric acid which stains the wool deep yellow, other colouring matters are thereby separated from the beer, which gives to the whole a dingy brown yellow colour. The presence of picric acid may, however, be detected with certainty by warming the wool with aqueous ammonia, filtering, concentrating to a small bulk on the water bath, and adding a few drops of solution of potassium cyanide. If the smallest trace of picric acid be present a red coloration will then be produced, due to the formation of potassium isopurpurate.

$$\underset{\text{Picric Acid.}}{C_6H_3(NO_2)_3O} + \underset{\text{Cyanogen.}}{3HCN} + \underset{\text{Water.}}{H_2O} = \underset{\text{Carbonic Acid.}}{CO_2} + \underset{\text{Ammonia.}}{NH_3} + \underset{\text{Isopurpuric Acid.}}{C_8H_5N_5O_6}$$

By this method one milligram (0·154 grain) of picric acid may be detected in a pint of beer.

T. J. HERAPATH gives an accurate and rapid method for the detection of the active principle of *cocculus indicus* (*picrotoxin*) in beers. It is based upon the property which charcoal possesses of separating picrotoxin from its aqueous solution. An excess of acetate of lead is added to the beer under examination, in order to throw down the humulin and other extractive matters; the precipitate is removed by filtration; and the excess of lead in the filtrate abstracted, by transmitting a current of sulphuretted hydrogen gas through it, when it will fall down as sulphide of lead. To expel the free sulphuretted hydrogen after the filtration of the precipitate, the solution is boiled for some time, then slowly evaporated, until the residue assumes a thick consistency; a small quantity of pure animal charcoal is then agitated with it for a few minutes.

When the whole cools, the solution is filtered, and the charcoal, containing the picrotoxin, washed with the smallest possible quantity of water, then dried at 212° Fahr. (100° C.). After all the moisture is expelled, the charcoal is next boiled with some pure alcohol to dissolve the alkaloid accompanying it, the solution is filtered and evaporated, and the picrotoxin permitted to crystallize spontaneously.

If the adulterant be present in large quantities, it is deposited in the well-formed prisms—Fig. 35—or when the solution is rapidly concentrated, and speedily cooled, the crystals have a beautiful foliated or feathery appearance, similar to Fig. 36.

A small amount of this ingredient assumes the form of long radiating needles, which if the crystallization be conducted between two slips of glass,

Fig. 35.

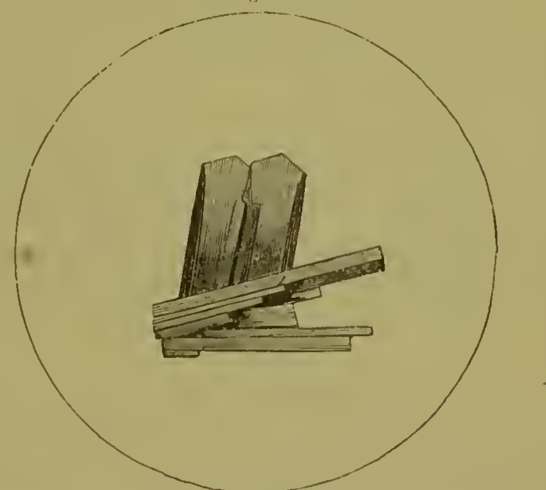


exhibit a peculiar tendency to place themselves nearly parallel with the edges of the upper glass. See Fig. 37.

It is said that by this means the alkaloid can be detected in the beer, when only half an ounce of the extract of picrotoxin has been added to the barrel.

Fig. 36.

BLAS, in his process, removes the hop bitters by shaking up 6 litres of the beer (previously evaporated to a small bulk and after saturation with soda) with one-tenth of its volume of ether; the residue is then acidified, and on again shaking with ether, the picrotoxin goes into solution, and is obtained as an intensely bitter mass on evaporating off the ether. This mass is dried in a water bath, taken up with alcohol acidified with one drop of acetic acid, and

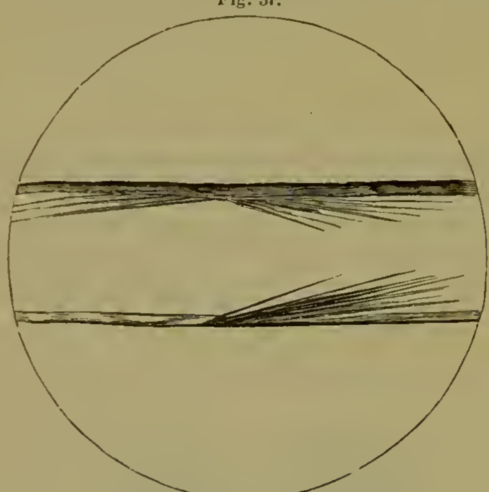
the filtered solution evaporated on a watch glass: if no distinct crystals are obtained, alcohol is added and recrystallization resorted to.

Picrotoxin crystals can be identified by their appearance (Figs. 35, 36, 37), their easy solubility in alcohol, bitterness, and the action of their solution on fishes.

Two fishes of about half an ounce weight are to be placed in 2 litres of water, and a portion of a solution of the crystals obtained as above is then added (this solution is made by dissolving the supposed picrotoxin in alcohol, adding water and boiling to drive off the alcohol); if it be really picrotoxin, the fish soon turn on their backs and die. Lupulin has not this poisonous action on fish. From 1 to 2 grammes of hops may be boiled in water and poured into the jar containing the fish without affecting them.

Two grammes of *cocculus indicus*, corresponding to 0·1 gram. of picrotoxin, is sufficient to kill a fish of a quarter to half an ounce in weight in ten hours.

Fig. 37.



If the residue, after shaking twice with ether as above, has a bitter taste, this points to the presence of salicin, quassin, and menyanthin. The liquid must then be precipitated with lead acetate; the filtrate freed from excess of lead, and mixed with tannic acid; the resulting precipitate warmed with alcohol and hydrated lead oxide; and the filtrate specially tested.

BLAS' process is varied thus, by DEPAIRE:—

The beer is shaken with common salt (360 grammes to the litre) and filtered; the filtrate shaken twice with ether; the residue from evaporation of the ethereal solution dissolved in alcohol: 15 c.c. of water and one drop of sulphuric acid added to the solution; the liquid heated for fifteen minutes in the water bath, cooled, filtered, and shaken with ether; the ethereal solution evaporated; and any crystals thus obtained recrystallized from alcohol and examined as above directed.

HOFFSTEDT'S process for the detection of spurious bitters in beer is thus translated in URE'S "Dict. of Arts," &c., vol. i. p. 332. It is applicable to the detection of picrotoxin, absinthin, menyanthin, quassin, and colocynthin.

The bitter principles likely to occur in beer may be divided into two classes. those which are precipitated by acetate of lead, and those which are not so thrown down.

1. Precipitable by acetate of lead:—

Lupulin.—It is not precipitable by tannin. It is soluble in alcohol and ether, but not in water.

2. Not precipitated by acetate of lead.

With tannin, after removal of lead by means of sulphuretted hydrogen.

a. Not precipitated by tannin:—

Picrotoxin.—Soluble in water, alcohol, and ether.

Absinthin.—Soluble in alcohol and ether, not in water.

b. Precipitated by tannin:—

Menyanthin.—Sparingly soluble in ether and cold water; easily in hot water. Turns brown and then violet with strong sulphuric acid.

Quassin.—Sparingly soluble in ether; soluble in 222 parts of cold water; not coloured by sulphuric acid.

Colocynthin.—Insoluble in ether; soluble in cold water. Turns first red and then brown with strong sulphuric acid.

The quantities needful for examination are 6 litres of bitter or Bavarian beer, or 4 of porter. This may seem excessive, but it must be remembered that a very small quantity of the above-mentioned drugs will impart a strong bitter taste to a large volume of liquid; and again, that the hop is never entirely omitted, since its peculiar efficacy in preventing spurious or secondary fermentation appears to be possessed by no other bitter.

The beer in question is to be evaporated down, first over the naked fire, and afterwards in the water-bath. Great care must be taken that it does not dry or burn on the sides of the vessel, or bitter principles may be generated and mask the reactions to be sought for. The thick mass is well treated with alcohol in a tall beaker. At the bottom will be found a thick gummy mass, and a somewhat turbid stratum of liquid over it. This is set aside to become clear; it is then poured off and the alcohol distilled off; the residue is concentrated to a syrup, and dissolved in alcohol. The solution is mixed with ten times its bulk of ether, which precipitates sugar; when clear, the liquid is decanted from the sediment and distilled. The residue is dissolved in warm water, and a portion of it tested with tannin. A pure well-hopped beer never gives a clear aqueous solution; a beer containing a little of the hop may; if the solution does not clear up, add a trace of alcohol. Besides lupulin, absinthin is insoluble in water. Filter off the resinous matter which may have been deposited, then precipitate the warm filtrate with acetate of lead, which must not be too acid; lupulin is then thrown down. Excess of lead must be carefully avoided, or menyanthin may fall down also: allow it to settle, filter, and wash the precipitate with hot water.

Filtrate.—Treat with sulphuretted hydrogen till all

the lead is precipitated; filter and wash, first with warm water, and then with alcohol; remove sulphuretted hydrogen and free acetic acid by evaporation almost to dryness. If the residue is free from bitterness, no adulteration is present; absinthin never gives a clear aqueous solution, and menyanthin never a clear cold one. A turbid solution may contain all the spurious bitters; add a little alcohol till the solution becomes clear, and then tannin.

1. The precipitate formed is dried along with the hydrated oxide of lead suspended in water, and extracted with boiling spirit. In the residue of this extract colocynthin, menyanthin, and quassin, are separated by means of their behaviour with ether and water.

2. The precipitate is freed from tannin by means of acetate of lead, the precipitate filtered off, the lead removed by means of sulphuretted hydrogen, and evaporated. Picrotoxin separates out in crystals; absinthin remains as a yellow mass.

LEVIN ENDER recommends the following mode of proceeding:—

1. Precipitate with acetate of lead.

Lupulin.—It gives no mirror with ammoniacal solution of silver.

2. Not precipitated by acetate of lead, but by tannin.

a. Soluble in ether. *Absinthin* gives a mirror with the silver solution.

b. Sparingly soluble in ether. *Menyanthin*, *Quassin*. The former gives a mirror, the latter not.

Picrotoxin, absinthin, menyanthin, colocynthin, reduce solution of silver; lupulin and quassia do not.

A. DRAGENDORFF has recently made experiments on the bitter constituents of quassia, *Ledum palustre*, absinthe, *Menyanthes trifoliata*, *Cnicus benedictus*, *Erythræa centaureum*, gentian, willow bark, aloes, picric acid, colocynth, *cocculus indicus*, colchicum seeds, *Daphne mezereum*, *Capsicum annuum*, *belladonna*, *hyoscyamus*, *nux vomica*, and juniper berries.

He gives the following general methods of detection:—

1. 600 to 1000 c.c. of beer are evaporated to a syrupy consistence in the water bath, and then treated with 3 to 4 volumes of alcohol as free as possible from fusel oil, and the mixture allowed to stand for twenty-four hours. The whole is then filtered; the alcohol is distilled off from the filtrate, and the residual liquid is again filtered after standing from twelve to twenty hours in the cold. A few drops of dilute sulphuric acid are then added, and the whole is agitated with petroleum ether; the supernatant petroleum layer is washed with water, filtered through dry filter paper to remove the last traces of water, and evaporated to dryness on several watch glasses by spontaneous evaporation. The aqueous acid liquor is then agitated with benzene and with chloroform, and then again with benzene after addition of ammonia, to liberate alkaloids. Salicin from willow bark is extracted by agitating the aqueous liquor with amylic alcohol.

2. 600 to 1000 c.c. are heated till most of the dissolved carbonic acid is driven off; after cooling, basic lead acetate is added till no further precipitate is formed; after standing for some hours the whole is filtered; diluted sulphuric acid is then added to throw down the excess of lead; if the filtrate has a harsh or bitter taste the beer is suspicious; the whole is then evaporated in the water bath (after neutralization by ammonia) as quickly as possible, until only 180 to 200 c.c. are left, and then treated with benzene, petroleum ether, and chloroform, as in method 1.

Normal beer, examined by method 1, should give the following results. The petroleum ether extract contains:—

1. An amorphous, slightly bitter substance, soluble in ether and alcohol, and partially soluble in water.

2. A substance which precipitates basic lead acetate.

3. A substance which becomes red with FRÖHDE'S reagent.

4. A substance which becomes red with sulphuric acid and sugar.

The benzene extract contains the same substances, and is more bitter; in addition it contains—

5. A body which becomes dark brown on treatment with sulphuric acid.

6. A substance which precipitates tannin.

The chloroform extract contains substances 1, 2, 5, and 6, in some instances in large proportions; also,

7. Pieces of a body precipitable by potassium iodide and phosphomolybdic acid.

8. A body which reduces ammoniacal silver nitrate.

9. A body crystallizable from ether, and with difficulty soluble in alcohol.

Of these substances, 2, 3, and 6 come from the hops; 1 from hops and malt together; 4, 5, 7, and 8 from malt; and 9 is formed from malt in fermentation.

The characters of the extracts obtained by the aid of the several solvents from the plant and vegetable products above mentioned having been carefully examined, and the reactions of the bitter ingredients thus isolated observed when treated with tannin, chloride of gold, basic lead acetate, ammoniacal silver solution, concentrated sulphuric acid, FRÖHDE'S reagent, sulphuric acid and sugar, sulphuric acid with five equivalents of water ($H_2SO_4 + 5H_2O$), caustic potash solution, ferric chloride, DRAGENDORFF constructed the following scheme, by which he states that, 600 c.c. of beer being taken for examination, 0·0005 gram. of atropine (= 0·06 gram. of belladonna leaves), 0·005 gram. of hyoscyamine (= 0·25 gram. of henbane), 0·0003 of strychnine, and 0·0005 gram. of brucine (= 0·03 gram. of nux vomica), can be detected.

Extract from Acid Liquor.

I. *Residue from Petroleum*—

a. Amorphous, first becomes brown, then violet, and soon red-violet, with sulphuric acid, *Traces of Absinthin.*

b. Amorphous, colourless, sharp-tasting, and rubefacient; coloured brown-red with sulphuric acid, *Traces of Capsicin.*

c. Amorphous, green, becomes red with sulphuric

acid and sugar; no precipitate with ammoniacal silver solution, *Juniper berry resin*.

d. Crystalline, yellow, becomes blood-red with potassium cyanide, *Picric acid*.

Residue from Benzene—

A. Crystalline, not bitter; becomes purple-red with potash, and red becoming orange with sulphuric acid, *Aloëtin*.

B. Amorphous—

a. No precipitate with gold chloride when residue is dissolved in water.

1. Tannin gives no precipitate, residue sharp tasting.

α. Sulphuric acid colours red brown, *Capsicin*.

β. Sulphuric acid colours brown, *Daphne bitter*.

2. Tannin precipitates the aqueous solution; residue bitter or bitterish.

I. Basic lead acetate causes slight turbidity; sulphuric acid and sugar hardly redden.

aa. Ferric chloride gives brown green tint on warming aqueous solution, slightly bitterish; *Gentian leaves*.

bb. Ferric chloride gives brown tint on warming; peculiar taste intolerably bitter, *Quassin*.

II. Basic lead acetate gives copious precipitate; sulphuric acid and sugar quickly give cherry-red tint; weakly bitterish, *Cnicin*.

b. Aqueous residue of solution does not act on gold chloride in the cold, but reduces on warming.

α. Tannin slightly precipitates; does not reduce ammoniacal silver solution; heated with dilute sulphuric acid gives odour of *ericinol;* FRÖHDE'S reagent colours it black-brown; sulphuric acid and sugar a beautiful red, *Ledum bitter*.

β. Tannin precipitates; ammoniacal silver reduced; heated with dilute sulphuric acid gives a slight odour of menyanthol, *Trifolium bitter*.

c. Aqueous solution of residue precipitates gold chloride in the cold, but does not reduce it on heating; with $H_2SO_4 + 5H_2O$ gives a slight odour of benzoic acid, *Centaury bitter*.

d. Aqueous solution of residue precipitates gold chloride in the cold, and reduces it on warming; sulphuric acid dissolves to a brown tint at first, soon turning violet, and becoming a beautiful violet on addition of water; hydrochloric acid of sp. grav. 1·135, colours it first green and then a beautiful blue, *Absinthin*.

Residue from Chloroform—

A. No precipitate and no reduction with gold chloride.

a. Tannin gives no precipitate; sharp taste; epispastic; sulphuric acid colours dark brown red, *Capsicin*.

b. Tannin precipitates.

α. Basic lead acetate gives considerable precipitate; heated with sulphuric acid it becomes turbid, then brown-red, giving a faint odour of benzoic acid, *Cnicin*.

β. Basic lead acetate gives little or no precipitate.

I. Sulphuric acid gives a brown colour.

aa. Residue very bitter, *Quassin*.

bb. Residue bitterish, *Gentian*.

cc. Residue sharp-tasting, *Daphne bitter*.

II. Sulphuric acid gives a slight yellow tint, or no colour at all, *Colocynth*.

B. Gold chloride gives no precipitate in the cold, but is reduced on warming.

a. Tannin does not precipitate.

1. Stupefies fish; bitter taste, *Picrotoxin*.

2. Tasteless or slightly bitter; potash colours red-brown, *Aloes*.

b. Tannin precipitates.

α. Ammoniacal silver reduced; strong odour of menyanthol on heating with sulphuric acid, or FRÖHDE'S reagent, *Menyanthin*.

β. Ammoniacal silver not reduced; odour of ericinol with dilute sulphuric acid, or with FRÖHDE'S reagent; beautiful carmine red on long standing with sulphuric acid and sugar, *Ericolin*.

C. Gold chloride precipitates in the cold, and is not reduced on warming; nitric acid gives a violet tint, *Colchicum*.

Heated with sulphuric acid, gives an odour like trifolium, then the liquid becomes red, and the smell alters to one resembling benzoic acid, *Centaury bitter*.

D. Gold chloride precipitates in the cold, and reduces on heating; sulphuric acid colours brown, and gradually dirty violet, *Wormwood bittter*.

Extract from Alkaline Liquor.

I. *Benzene Residue*.

a. Dilates the pupil of a cat's eye.

1. Platinum chloride does not precipitate the aqueous solution; peculiar odour on warming with sulphuric acid, *Atropine*.

2. Platinum chloride precipitates when in just the right proportion, *Hyoscyamine*.

b. Does not dilate the pupil of a cat's eye.

1. Sulphuric acid solution becomes blue with bichromate of potassium or ceric oxide, *Strychnine*.

2. Sulphuric acid solution becomes red with nitric acid, *Brucine*.

II. *Amylic Alcohol residue* (examined only when salicin is to be sought for).

Heated with sulphuric acid and bichromate of potassium gives a salicilous odour, *Salicin*.

Ash of Beer.—The following are examples of the percentage composition of the ash of beer, the first three analysed by WALZ, the rest by DICKSON:—

	London Beer.	München Beer.	Speyer Beer.	Scotch Ale (14 samples).	Scotch Porter (2 samples).	Dublin Porter (2 samples).	London Porter (5 samples).
Potash,................	38·35	36·58	37·68	3·2 — 29·8	18·9 — 20·9	21·4 — 32·0	4·9 — 31·1
Soda,................	7·68	9·03	6·59	20·9 — 38·5	33·8 — 38·8	24·0 — 42 7	21·8 — 50·8
Lime,................	2·45	1·48	2·98	0·2 — 2·0	1·3 — 1·6	0·8 — 1·5	0·8 — 6·9
Magnesia,..............	3·78	5·64	4·66	0·1 — 5·6	0·2 — 1·4	0·2 — 1·2	0·1 — 1·2
Sulphuric acid (SO_3),.....	1·36	1·68	2·56	1·6 — 19 2	2·2 — 6·4	2·8 — 10·1	1·6 — 12·2
Chlorine,..............	2·75	3·14	2·14	4·3 — 18·25	7·4 — 11·4	6·9 — 10·1	6·5 — 14·5
Silica,................	9·87	9·96	10·29	4·6 — 19·1	13·3 — 18·6	6·9 — 19·7	8·25 — 19·7
Phosphoric acid (P_2O_5),...	33·76	31·69	33·10	6·0 — 25·7	12·2 — 18·8	7·9 — 20 0	9·3 — 20·6
	100·00	100·00	100·00				

The following tables from WATT'S "Dict. of Chemistry," vol. i. p. 533, exhibit the composition of various kinds of beer:—

AVERAGE AMOUNT OF MALT EXTRACT AND ALCOHOL.

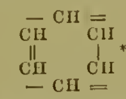
Name of Beer.	Percentage of Malt Extract.	Percentage of Alcohol.
London Ale, for exportation,.	7 — 5	6 — 8
London Ale, ordinary,......	5 — 4	4 — 5
London Porter, for exportation,	7 — 6	5 — 6
London Porter, ordinary,....	5 — 4	3 — 4
Brussels Lambick,..........	5·5 — 3·5	4·5 — 6
Brussels Faro,..............	5 — 3	2·5 — 4
Bière Forte de Strasbourg,...	4 — 3·5	4 — 4·5
Bière Blanche de Paris,......	8 — 5	3·5 — 4
Bavarian Beer,...	6·5 — 4	3 — 4·5
White Beer of Berlin,.......	6·2 — 5·7	1·8 — 2

SPECIAL RESULTS OF THE EXAMINATION OF CERTAIN BEERS.

Name of Beer.	Malt Extract. per cent.	Alcohol. per cent.	Carbonic Acid. per cent.	Water. per cent.	Analysed by
London Porter (Barclay & Perkins),....	6·0	5·4	0·16	88·44	Kaiser.
London Porter, ...	6·8	6·9	*	86·3	Balling.
London Porter (Berlin),.	5·9	4·7	0·37	89·0	Zinrek.
Burton Ale, ...	14·5	5·9	*	79·6	Hoffmann.
Scotch Ale (Edinburgh),	10·9	8·5	0·15	80·45	Kaiser.
Ale (Berlin), ...	6·3	7·6	0·17	85·93	Ziurek.
Brussels Lambick, ...	3·4	5·5	0·2	90·9	Kaiser.
Brussels Faro,..........	2·9	4·9	0·2	92·0	Kaiser.
Salvator Bier (München),	9·4	4·6	0·18	85·85	Kaiser.
Bock Bier (München), ..	9·2	4·2	0·17	86·49	Kaiser.
Bavarian Draught Beer (*Schenk Bier*, München),.............	5·8	3·8	0·14	90·26	Kaiser.
Bavarian Store Beer (*Lager Bier*, München), 16 months old,	5·0	5·1	0·15	89·75	Kaiser.
Bavarian Store Beer (München),........	3·9	4·3	0·16	91·64	Kaiser.
Bavarian Draught Beer (Brunswick),.......	5·4	3·5	*	91·1	Otto.
Bavarian Beer (Waldschlösschen),.......	4·8	3·6	*	91·5	Fischer.
Prague Draught Beer, ..	6·9	2·4	*	90·7	Balling.
Prague Town-beer (*Stadt-bier*),........	10·9	3·9	*	85·2	Balling.
Sweet Beer (Brunswick),	14·0	1·36	*	84·7	Otto.
Josty's Beer (Berlin),....	2·6	2·6	0·5	94·3	Ziurek.
Werder's Brown Beer (Berlin),...........	3·1	2·3	0·3	94·2	Ziurek.
White Beer (Berlin),....	5·7	1·9	0·6	91·8	Ziurek.
Bière Blanche de Louvain,	3·0	4·0	*	93·0	Le Cambre.
Petermann (Louvain),...	4·0	6·5	*	89·5	Le Cambre.
Mum (Brunswick),......	45·0	1·9	*	53·1	Freytag and Busse.

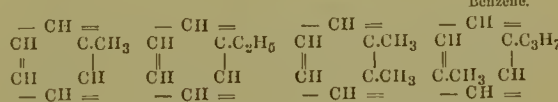
BENZOL.—The term "benzol" is commercially applied to a mixture of bodies, for the most part consisting of the hydrocarbon benzene† and its higher homologues.

The mutual relations of bodies of this description are conveniently indicated by a symbolic device introduced by KEKULÉ. The quantitative analysis of the hydrocarbon benzene is capable of being indicated by the empirical formula, CH; but as its vapour density is found to be 39 times that of hydrogen, the rational formula, C_6H_6, is applied to it in accordance with modern conventions. KEKULÉ has pointed out that the chemical changes occurring with the numerous class of substances known as the "benzene derivatives," or "aromatic compounds," may be conveniently expressed in brief by breaking up or dissecting the rational formula of benzene into six trivalent groups of symbols (radicals) arranged symmetrically thus—



the formulæ of benzene derivatives being deducible from this parent formula by replacing, by other radicals, an equivalent number of H symbols. When the radicals thus caused to replace H symbols are univalent hydrocarbon radicals of the methyl series, the formula of higher homologues of benzene are obtained; these and other analogous radicals are referred to as lateral chains of symbols; or, briefly, lateral chains:—

Toluene. Ethyl Benzene. 1.2 Dimethyl Benzene. 1.4 Propyl Methyl Benzene.



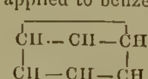
It is noteworthy that the homologues of benzene that make up the main portion of commercial benzol are all related to benzene in this way, that the lateral chains in these formulæ always consist of the radical methyl, CH_3, and not of any higher homologous radical; it is, in fact, not proved with certainty that any other kinds of homologues are present, at any rate in coal-tar benzols. Ethyl benzene and methyl-ethyl benzene are stated to exist in these oils, but the evidence of their presence is as yet very incomplete; these and other analogously constituted bodies are therefore omitted from the following list of constituents of benzol:—

Name.	Rational formula.	Partially dissected formula.	Boiling point.	Melting point.
Benzene,.......	C_6H_6		80	$+5°·5$
Toluene,........	C_7H_8	$C_6H_5.CH_3$	111	Not solid at —20°
Xylene,........	C_8H_{10}	$C_6H_4\begin{cases}CH_3\\CH_3\end{cases}$	139	
Isoxylene,.......	C_8H_{10}	$C_6H_4\begin{cases}CH_3\\CH_3\end{cases}$	137 — 138	
Pseudo-cumene,	C_9H_{12}	$C_6H_3\begin{cases}CH_3\\CH_3\\CH_3\end{cases}$	166°	
Mesitylene, ...	C_9H_{12}	$C_6H_3\begin{cases}CH_3\\CH_3\\CH_3\end{cases}$	163°	
Tetra-methyl benzene,....	$C_{10}H_{14}$	$C_6H_2\begin{cases}CH_3\\CH_3\\CH_3\\CH_3\end{cases}$	About 180°	

* Not determined quantitatively.

† It is convenient to apply, wherever practicable, a name terminating in *ene* to a hydrocarbon (*e.g.*, ethylene, benzene, terpene, anthracene, naphthalene, &c.), the terminal *ol* being applied to bodies containing oxygen (*e.g.*, alcohol, phenol, absinthol, thymol, &c.). The word "benzol" is here applied to the commercial mixture of hydrocarbons, and not to any one constituent of the mixture.

* Another dissected formula, also consisting of six trivalent radicals, is sometimes applied to benzene, viz.:—



this only differs from the hexagonal formula in certain minor respects, and for most purposes may be regarded as identical therewith.

It is noticeable that in this list two different bodies occur, each denoted by the partially dissected formula, $C_6H_4 \begin{cases} CH_3 \\ CH_3 \end{cases}$; and also two, each indicated by $C_6H_3 \begin{cases} CH_3 \\ CH_3 \\ CH_3 \end{cases}$; a third isomeride of the former pair is also known (but not with certainty as a constituent of benzol), indicated by the same formula, $C_6H_4 \begin{cases} CH_3 \\ CH_3 \end{cases}$; this body boils at 140° to 141° C.

KEKULÉ'S notation affords a most convenient mode of distinguishing between such isomerides, when neither the rational nor the partly dissected formula enables any distinction to be made; moreover, the number of isomerides of any given kind actually known with certainty is never greater than the number that can be thus indicated. All the H symbols in the hexagonal benzene formula being of equal function, it is manifest that the same formula results when only one H symbol is replaced by a given radical, no matter which of the six symbols be operated on; in practice, no isomerism in benzene derivatives of this class is known. When, however, two H symbols are thus replaced, three distinct formulæ result, according as the two H symbols operated on are adjacent, next but one, or opposite to each other; thus the three dimethyl benzenes referred to may be distinguished by the respective formulæ.

```
 — CH =            — CH =            — CH =
CH    C.CH3       CH    C.CH3       CH    C.CH3
||    |           ||    |     and   ||    |
CH    C.CH3       CH    CH          C.CH3 CH
 — CH =            — C.CH3 =         — CH =
```

In the same kind of way, when three H symbols are replaced, numerous formulæ may be written, differing in the relative positions occupied in the formula by the lateral chains, or radicals substituted for H symbols. The number of formulæ ascribable to any given kind of derivative is as yet never less than the number of distinct isomerides of that kind actually known with certainty.

To distinguish briefly between such bodies as the above dimethyl-benzenes the terms 1.2. dimethyl benzene, 1.3. dimethyl benzene, 1.4. dimethyl benzene, are used according to the relative positions of the lateral chains. The prefixes ortho, meta, and para, are also employed to distinguish between the three formulæ ascribable to benzene derivatives where two H symbols are replaced. Unfortunately chemists are not in accord as to which prefix is to be applied to the 1.2. 1.3. 1.4. formulæ respectively, some applying ortho to the first and meta to the second, others *vice versa*; hence it is preferable to apply these prefixes not in reference to the position of the radicals, or the formula ascribed to the body (which in many instances is quite arbitrary), but according as the body can be transformed by reactions of exchange into one or other of three isomeric varieties of a given class of derivatives, *e.g.*:—

	Dihydroxyl benzene.	
Ortho,	$C_6H_4(OH)(OH)_o$,	Hydroquinone.
Meta,	$C_6H_4(OH)(OH)_m$,	Pyrocatechin.
Para,	$C_6H_4(OH)(OH)_p$,	Resorcin.

	Dicarboxyl benzene.
Phthalic acid,	$C_6H_4 \begin{cases} CO_2H \\ (CO_2H)_o \end{cases}$
Isophthalic acid,	$C_6H_4 \begin{cases} CO_2H \\ (CO_2H)_m \end{cases}$
Terephthalic,	$C_6H_4 \begin{cases} CO_2H \\ (CO_2H)_p \end{cases}$

The suffixes *o m p*, applied to the radicals constituting the lateral chains, thus indicate the reactions of the kind undergone by the body in question: thus, the xylene of coal ores boiling at 139° is paradimethyl benzene, $C_6H_4 \begin{cases} CH_3 \\ (CH_3)_p \end{cases}$, as it yields terephthalic acid by oxidation, whilst the isoxylene simultaneously present is metadimethyl benzene, as it forms isophthalic acid, $C_6H_4 \begin{cases} CH_3 \\ (CH_3)_m \end{cases}$, by the same process.

A circumstance limiting the utility of this convenient short-hand system is, that it not unfrequently happens that the same substance by one train of reactions gives rise to a body belonging to the, say, para series, and by another series of reactions to one belonging to the, say, meta series: in a case of this kind "alteration of relative position of lateral chains" is said to occur at some one of the stages.

Benzene.—This hydrocarbon was first discovered by FARADAY in 1825, in the liquid which resulted from the compression of illuminating gases produced by the destructive distillation of oil. From its empirical formula, C_2H (where $C = 6$ and $H = 1$), he termed it *bicarburet of hydrogen*. In 1836 MITSCHERLICH obtained it by heating benzoate of calcium, whence the name *benzol* (or *benzene*, as it is now preferably termed. *Vide* p. 341). HOFMANN in 1845 discovered its existence in coal tar, and soon after (1847) MANSFIELD proposed to separate it (in an impure state) therefrom by distillation, in order to employ it as a carburizer for gas of weak illuminating power. Its application to the removal of grease and the manufacture of artificial essence of almonds soon followed; and finally the discovery of aniline dyes caused an enormous increase in the trade in this substance.

Besides occurring in the tar of coals, benzene and its homologues are formed by the destructive distillation of many organic substances, *e.g.*, wood, turf, resin, &c.; and they also occur in various natural petroleums and naphthas, such as Rangoon tar (DE LA RUE and MÜLLER), petroleum of Sehnde, Hanover (BUSSENIUS and EISENSTÜCK), naphtha from Boroslaw, Galicia (PEBAL and FREUND). In the early days of the aniline dye industry attempts were made to utilize some of these sources, but it was soon found that coal tar was a far cheaper and better source. VOGEL examined in 1858 a sample of so-called benzol, which contained much oxidized matter and began to boil at 102°, whilst in the same year SCHIFF found that a specimen contained wood-spirit, methyl acetate, toluene, xylene, and higher homologues, but no trace of benzene!

Benzene is obtainable by heating, in contact with alkalies, any one of the numerous benzene-carboxyl acids. Thus—

Benzoic acid, ... $C_6H_5\ CO.OH = CO_2 + C_6H_6$

Phthalic acid, ... $C_6H_4\begin{cases}CO.OH\\CO.OH\end{cases} = 2CO_2 + C_6H_6$

Trimesic acid, ... $C_6H_3\begin{cases}CO.OH\\CO.OH\\CO.OH\end{cases} = 3CO_2 + C_6H_6$

Pyromellitic acid, .. $C_6H_2\begin{cases}CO.OH\\CO.OH\\CO.OH\\CO.OH\end{cases} = 4CO_2 + C_6H_6$

Also, by heating in a sealed tube acetylene, which then polymerizes; $3C_2H_2 = C_6H_6$ (BERTHELOT). Also, by the action of heat on the vapour of many other hydrocarbons, *e.g.*, xylene, chrysene, naphthalene, diphenyl, &c. (BERTHELOT). None of these processes are of practical use. It has been proposed to manufacture pure benzene from naphthalene by oxidizing that hydrocarbon to phthalic acid, and then heating this substance in contact with lime; but it is manifest such a process would be far too costly. Benzoic acid is, however, formed in this way by the intermediate reaction—

$$\underset{\text{Phthalic Acid.}}{C_6H_4\begin{cases}CO.OH\\CO.OH\end{cases}} = CO_2 + \underset{\text{Benzoic Acid.}}{C_6H_5.CO.OH},$$

to an extent sufficient to make it applicable for the manufacture of that body (P. & E. DEPOUILLY).

Pure benzene boils at 80°·4 (KOPP), 80° to 81° (MANSFIELD), 82° (FREUND); it has the specific gravity 0·85 at 15° (FARADAY and MITSCHERLICH), 0·899 at 0° (KOPP); it solidifies, on cooling, to a crystalline mass, which melts at 5°·5; nitric acid converts it into nitrobenzene, $C_6H_5(NO_2)$, and by further action into dinitrobenzene, $C_6H_4(NO_2)_2$: it readily dissolves fatty and essential oils, whence its use for cleaning clothing, and for the extraction of oil and grease from seeds, oil-cake, wool, &c., &c. It is most conveniently obtained pure by fractional distillation of commercial benzol (*vide* p. 345), and successive crystallization of the lowest distillates.

Toluene.—This hydrocarbon was found by PELLETIER and WALTER, in 1838, in the liquid condensed by compressing resin gases, and was described by them under the name of *retinaphtha*. NOAD obtained it in 1847 by heating toluic acid with excess of baryta, its mode of formation being identical with that benzene from benzoic acid; hence the name tolnol (or toluene —*vide* p. 341).

$$\underset{\text{Toluic Acid.}}{C_6H_4\begin{cases}CH_3\\CO.OH\end{cases}} = CO_2 + \underset{\text{Toluene.}}{C_6H_5.CH_3}.$$

It is present in coal tar (MANSFIELD, 1847), wood tar (CAHOURS), Rangoon tar (DE LA RUE and MÜLLER), and the product of the distillation of tolu balsam (DEVILLE) and of dragon's blood (GLENARD and BOUDAULT). It can be synthetically formed by the action of sodium on a mixture of phenyl and methyl bromides (FITTIG and TOLLENS)—

$$C_6H_5Br + CH_3Br + Na_2 = 2NaBr + C_6H_5.CH_3;$$

and by the distillation of benzoate and acetate mixed together (BERTHELOT), or by the action of alcoholic caustic potash on benzoic alcohol (CANNIZARO), and by several other reactions.

When required pure and in quantity, it is most conveniently extracted from commercial benzol by fractional distillation (*vide* p. 345); smaller amounts are readily obtainable from dragon's blood or from tolu balsam. Pure toluene much resembles benzene in general properties, save that it does not solidify on cooling to —20°. Its specific gravity is 0·8824 at 0°, and 0·875 at 20°; its boiling point is 110° to 111°. No isomeric modification of it is known;* although it gives rise to two (and possibly three) isomeric nitro-toluenes on nitration; each of these reproduces the same original toluene on reduction by hydriodic acid (ROSENSTIEHL).

Xylene.—Three dimethyl benzenes are known, one of which, orthoxylene, has not yet been shown to exist in coal tar: the other two were confounded together until 1869, when FITTIG showed that coal tar xylene is really a mixture of two isomerides.

Para-xylene, or methyl toluene, is obtainable by the action of sodium on a mixture of brominated toluene and methyl iodide or bromide (FITTIG and GLINZER)—

$$C_6H_4\begin{cases}Br\\CH_3\end{cases} + CH_3Br + 2Na = 2NaBr + C_6H_4\begin{cases}CH_3\\CH_3.\end{cases}$$

Meta-xylene, or isoxylene, is producible by heating mesitylenic acid (formed by the oxidation of mesitylene, $C_6H_3(CH_3)_3$) along with lime, the reaction being parallel to that whereby benzene is formed from benzoic acid or toluene from toluic acid (FITTIG.)

$$C_6H_3\begin{cases}CH_3\\CO.OH\\CH_3\end{cases} = CO_2 + C_6H_4\begin{cases}CH_3\\CH_3\end{cases}$$

or by similarly treating the isomeric xylylic acid (from the oxidation of pseudo cumene).

Ortho-xylene is formed by an analogous reaction, para-xylylic acid (formed along with the isomeric xylylic acid) being used instead of its isomeride (FITTIG and BIEBER). The following table indicates the main points of difference between these three hydrocarbons:—

	Para.	Meta.	Ortho.
Boiling point, ...	139° FITTIG & GLINZER. 136° JANNASCH.*	137° to 138°.	140° to 141°.
Products formed by oxidation with dilute nitric acid, ...	Para-toluic acid, melting at 176°.	Not attacked.	Orthotoluic acid, melting at 102°.
Do. with chromic acid, ...	Terephthalic acid.	Isophthalic Acid.	
Trinitro-xylene, ...	Melts at 137°	Melts at 177°.	

* CHURCH has described a "para-benzene" boiling at 97°·5, and not solidifying at —20°, and a "para-toluene" boiling at 119°·5, occurring in coal tar; the former giving rise to the same nitrobenzene as ordinary benzene boiling at 80°. These results have not been confirmed, and it seems probable that the bodies in question were only very impure benzene and toluene.

* JANNASCH has recently found (*Zeitsch. f. Chem.* [2] vii. 117) that the xylene obtained from pure solid bromotoluene and methyl iodide (para-xylene) is a solid crystalline substance, melting at 15° and boiling at 136°. Not improbably the bromotoluene used by FITTIG and GLINZER contained a little meta-bromotoluene.

The mixture of isomerides obtained from coal tar has recently been proposed as a remedial agent in cases of small-pox, doses of 3 to 5 drops (children) or 10 to 15 drops (adults) given every hour, or somewhat less frequently, having been found to produce remarkable results in cases of this disease.

GIRARD and DE LAIRE state that ethyl benzene ($C_6H_5.C_2H_5$) exists in that portion of coal oils that passes over between toluene and xylene, but cite no experimental evidence in support of the statement. ("Traité des Dérivés de la Houille," Paris, 1873, p. 47). This hydrocarbon boils at 133° to 135°.

Cumene.—Besides other isomerides, not known with certainty to occur in coal tar, two trimethyl benzenes are known occurring in commercial benzol; the discovery of the distinction between these was made by FITTIG in 1868.

Pseudo cumene, trimethyl benzene, or dimethyl toluene. This substance is obtained in a state of purity by the action of sodium on a mixture of methyl iodide or bromide, and brominated paraxylene. The same substance is produced also if metaxylene is substituted for paraxylene (FITTIG and JANNASCH.)

$$C_6H_3\begin{cases}Br\\CH_3\\CH_3\end{cases} + CH_3Br + 2Na = 2NaBr + C_6H_3\begin{cases}CH_3\\CH_3\\CH_3\end{cases}$$

Mesitylene.—This is obtained by the dehydrating action of sulphuric acid, &c., on acetone, and in various other ways, *e.g.*, the action of zinc chloride on camphor.

$$\underset{\text{Acetone.}}{3CO(CH_3)_2} = 3H_2O + \underset{\text{Mesitylene.}}{C_6H_3\,(CH_3)_3}.$$

$$\underset{\text{Camphor.}}{C_{10}H_{16}O} = CH_4O + \underset{\text{Mesitylene.}}{C_6H_3\,(CH_3)_3}.$$

The differences between these two hydrocarbons may be thus contrasted:—

Boiling point,..	Pseudo cumene, 166°	Mesitylene, 163°
Action of dilute nitric acid,..	Forms two isomeric acids, each indicated by $C_9H_{10}O_2$, viz. Xylylic melting at 120° Paraxylylic " " 163° By further action gives xylidic acid, $C_9H_8O_4$	Forms mesitylenic acid, also indicated by $C_9H_{10}O_2$, melting at 166°
Trinitro derivative,	Melts at 185°	Melts at 230° to 232°

Numerous other isomerides are known, *e.g.*, propyl benzene, methyl ethyl benzene, &c., but the occurrence of these in coal tar is not yet proved. By the action of nitrating agents on the mixture of hydrocarbons of formula C_9H_{10}, obtained from coal tar, three trinitro compounds are formed—viz., the trinitro pseudo cumene, and the trinitro mesitylene above mentioned, and also a third modification, melting at a lower temperature than either (FITTIG and WACKENRODER); hence it is not impossible that a third modification of the hydrocarbon is therein present. This has not yet been isolated, however, whilst the production of the *three* trinitro bodies is perfectly compatible with the existence of *two* hydrocarbons only.

Tetramethyl Benzene.—The existence of a benzene homologue higher than "cumol" in coal tar was signalized by MANSFIELD; but later researches seemed to indicate that the product thus obtainable by fractional distillation was very impure, containing naphthalene and mesitylene, &c., so that some doubt existed as to the presence at all of tetramethyl benzene in coal tar. BERTHELOT, however, has shown that the hydrocarbon boiling at 179° to 180°, and freed from naphthalene by a treatment with picric acid, has the composition $C_{10}H_{14}$, and differs from ordinary cymene (from cummin oil, camphor, &c.), and other hydrocarbons of formula $C_{10}H_{14}$, in the nature of the products formed by the action of hydriodic acid—viz., nothing but decane ($C_{10}H_{22}$) in the case of the coal-tar product; decane mixed with lower homologues corresponding with the various "lateral chains" present in the formula of the other isomerides, in these cases respectively.

A solid tetramethyl benzene melting at 79° to 80°, and boiling at 189° to 191°, has been obtained recently by FITTIG and JANNASCH, by the action of sodium on a mixture of brominated trimethyl benzene (pseudo cumene), and of methyl bromide. The existence of this body, termed *durol* (preferably *durene*, vide note, p. 341) by the discoverers, in coal tar is, however, not yet proved.

Manufacture of Benzol.—In the first rough distillation of tar (*vide* article COAL-TAR DISTILLATION) two fractions are obtained, known as "first light oils" and "second light oils." These contain considerable quantities of benzene and its homologues, usually consisting of the following ingredients in various proportions:—

	Boiling Point.
Ammonia, sulphide of ammonium, and other ammoniacal compounds,..............................	—
Hydrocarbons homologous with marsh gas, especially hexy hydride,..........................	68°—160°
Hydrocarbons homologous with olefiant gas, especially amylene, hexylene, and heptylene,.......	40°—100°
Benzene,..	80°
Toluene,..	111°
Higher homologous hydrocarbons,.................	137°—180°
Bases of the pyridine series, chiefly pyridine and picoline,..................................	117°—135°
Phenol (carbolic acid),.........................	187°
Higher homologues,..............................	—
Naphthalene,....................................	218°
Aniline (traces),...............................	182°

The quantity of substance of boiling point above 150° C. present, varies with the nature of the tar, the way in which the distillation is effected, &c.

To prepare "benzol" from these liquids slightly different methods are employed, according to the quality of the benzol ultimately required. For certain makes of aniline dyes a benzol of which 90 per cent. is volatile below 100° C. is required; for other purposes benzols of 80, 50, 30, &c., per cent., distilling below 100°, are prepared.

For the former quality the first light oils are usually treated separately; for the others the first and second light oils are mixed together and distilled by "wet steam"; sometimes the second light oils are thus distilled by wet steam, and the distillate treated along with the first light oils for 90 per cent.

benzols. By redistilling the "once run naphtha" thus obtained by means of wet steam in a still heated by a dry steam-worm, benzols of any required percentages may be obtained according to the temperature up to which the distillation is carried, which is known by means of a thermometer adjusted in the roof of the still, so that the temperature of the evolved vapour can be read off.

Besides benzol, the light oils contain another valuable constituent, viz., carbolic acid, which, together with various impurities, is usually removed from them by treatment with alkalies (lime, caustic-soda, soda-ash, &c.) and sulphuric acid before the extraction of benzol is proceeded with. For this purpose the light oils are mashed with about 5 per cent. of strong sulphuric acid in a lead-lined tub, furnished with an agitator worked by hand or by steam. Ammonia, pyridine, and other bases, and a portion of the ethylene homologues are thus dissolved out. Preferably the ammoniacal benzene may be treated with water first, so as to wash out ammoniacal compounds: this water can be used, together with the ordinary gas liquor, for making sulphate of ammonia. After standing some hours the acid is run off through a tap at the bottom of the tub; if necessary, a second treatment with sulphuric acid is proceeded with, the acid run off from this second process serving to purify another batch of hydrocarbon. Water, with which lime is stirred up (milk of lime), is then added, and the whole agitated for some time: carbolic acid, particles of sulphuric acid, &c., are thus removed. Finally, the hydrocarbon is washed with water, and after standing, run off to a still for a final distillation. Some manufacturers prefer to use either soda-ash or caustic-soda instead of lime; the last is, however, cheaper. GIRARD and DE LAIRE recommend the use of three cast-iron cylindrical tubs 1·6 mètre high and 2 in diameter, arranged at such levels that the oils drop into the first from the condenser, and can thence be run into the second and thence into the third by gravitation. In the first tub the hydrocarbon is agitated with water, which is run off by a syphon after standing: the hydrocarbon is then run into No. 2, which is lined with lead (soldered by the hydrogen blow-pipe) and furnished with a lead-covered agitator and with a kind of lid pierced all over with small holes. This tub serves for the sulphuric acid treatment, the object of the pierced lid being to divide the acid into small streams as it enters. A second treatment with acid is given if required, the spent acid being run off through a tap at bottom, and the hydrocarbon is then washed three or four times with water. Finally, it is run into No. 3, where it is treated with 2 to 3 per cent. of caustic-soda ley, at a specific gravity, 1·305; after thorough agitation, and twelve hours' repose, the spent ley is run off, and the hydrocarbon washed twice with pure water, being allowed to stand six hours after agitation in each case. ("Traité des Derivés de la Houille," 1873.)

It is scarcely necessary to say that, owing to the volatility and inflammability of the benzol, all the tubs must be covered closely; lids fitting on with water-lutes and pierced with a hole fitting to the agitator spindle are preferable.

According to the nature of the contracts on hand, or of the purposes to which the benzol is to be put, so the temperatures at which the distillates are collected are regulated. For the purpose of fuchsine making a benzol is required which will yield (by nitration and subsequent reduction) an aniline oil of which about three quarters distil between 180° and 190°, and one quarter between 190° and 215°; such an aniline oil is obtained from a benzol, of which about three quarters distil between 80° and 100°, and one quarter between 100° and 130° (REIMANN). For methyl violet, on the other hand, an aniline as free as possible from higher homologues is requisite, and this is made from a benzol very little of which passes over above 83° or 84°. Not unfrequently, however, colour manufacturers prepare aniline oils of various character from benzols of tolerably constant character supplied by contract, or prepared by a uniform process on the premises, these oils being then mixed in such proportions as may be required for the end in view.

For certain colours, *e.g.*, xylidine red, only aniline oils of very high boiling point are used. These come from benzols boiling above 115° or 120°; but it is more usual to prepare these special aniline oils by distillation of commercial aniline oils, reserving the last portions of high boiling point (*aniline tailings*, or *queues d'aniline*), than to prepare them from special benzols.

LETHEBY thus describes the distillation of benzol as carried on near London:—Steam is blown through the light oils (first and second mixed) at 20 to 30 lbs.; the once run naphtha thus produced is purified by sulphuric acid, &c., and then again distilled by blowing high pressure steam through, the distillate being collected in three fractions: the first is called "80 per cent. benzol," the second "50 per cent. benzol," whilst the last portions are used for dissolving indiarubber, &c., and are known as "solvent naphtha." The 50 per cent. benzol is distilled from a steam-jacketted still, that distilling up to a temperature of 210° being 80 per cent. benzol, and that between 210° and 260° 30 per cent.; the residuum is blown over with wet steam and added to the solvent naphtha. The 30 per cent. distillate is again distilled by dry steam, when it yields a little 80 per cent., distilling below 106°; between 106° and 234° 40 per cent. benzol passes over; and between 234° and 260° a little 30 per cent., a residuum of solvent naphtha blown over by wet steam being left; thus the oils are split up into 80 per cent. benzol, 40 per cent., and solvent naphtha. Finally, the 80 per cent. benzol is again distilled by dry steam; that passing over up to 104° is sold as 90 per cent. benzol; that between 204° and 210° is 80 per cent.; whilst the residue is blown over by steam and furnishes more 40 per cent. benzol.

For this kind of operation the following kind of double still may be employed—Still I. being used for the more volatile fractions, and II. for the higher boiling portions. (BENZOL, Plate I.):—I. Cylindrical

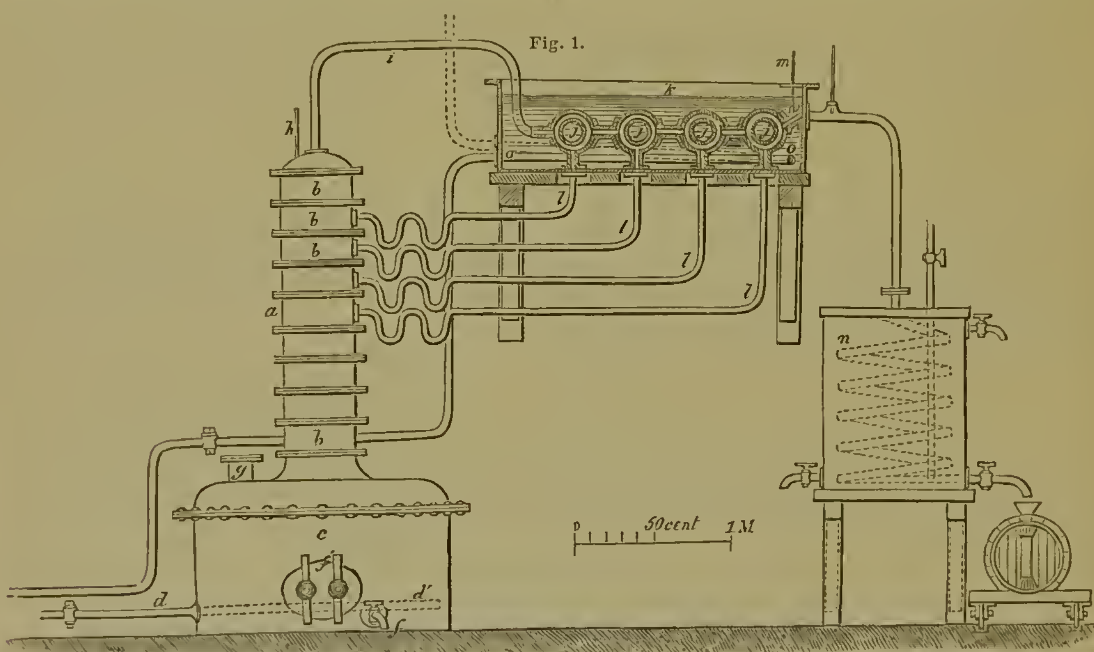
still; *a*, drawing-off cock; *b*, cock for drawing off condensed water from steam worm, *g g*; *c*, steam pipe; *d e*, cocks for connecting steam either with worm, *g g*, or with pipe, *f f*; *f f*, horizontal serpentine pierced with holes so as to blow steam through the still when required; *g g*, steam worm for heating still without admission of steam to the interior; *h*, pipe whereby the hydrocarbons are run into the still; *i*, manhole; *k*, exit pipe for hydrocarbon vapours; *l*, serpentine immersed in a tank of water, *m m*; *m m*, water tank for condensation of those constituents of evolved vapour which boil above 100°; *n*, cock for shutting off connection of still and condenser; *u*, receptacle for liquid spirted over; *v*, tap for drawing off liquid from *u*; *w*, pipe leading to condenser. II. Cylindrical still; *o o*, pipe leading to condenser; *p*, exit pipe for vapours; *q*, pipe whereby hydrocarbons are run into still; *r r*, horizontal serpentine pierced with holes so as to blow steam through still when required; *s*, drawing-off cock; *t*, cock for shutting off connection of still and condenser.

Still I. is 5 feet wide and 6 high, while II. is 5½ feet wide and only 5 high; the two stills, moreover, differ in that I. is provided with the steam worm, *g g* (which has fifteen turns, not all shown in the figure), and also with the condensation tank, *m m*.

When the lighter distillates are to be rectified, the cock, *t*, is closed and *n* opened; steam is let into the worm, *g g*, and the distillation effected. To blow over the last portions, the worm, *g g*, is shut off, and steam is blown in directly through the worm, *f f*. In distilling the higher boiling portions from II., the steam is simply blown in through *r r*, the cock, *t*, being opened and *n* being shut off.

GIRARD and DE LAIRE recommend as most convenient the following form of still, more especially for the final distillations of purified benzols. This still consists of a wrought or cast iron cylinder, about

Fig. 1.



1·8 mètre high and 2 in diameter, and holding 1000 to 2500 litres, resting on a solid brick and cement foundation; it is heated by a worm-tube of iron or lead through which steam at 3 to 4 atmospheres is passed; the passing over of the hydrocarbon is much facilitated by the injection of a jet of steam, but in this case the thermometer cannot be used as an indicator of the progress of the distillation, and hence fractional distillation is rendered impossible.

A process of fractional condensation, originally proposed by MANSFIELD in 1847 (Patent No. 11960, November 11, 1847), has been applied by COUPIER to the commercial preparation of hydrocarbons of the benzene family in a state of considerable purity. This consists in passing the vapour from the still through a worm, or a series of bulbs, immersed in a hot bath (water, saline solution, oil, paraffin, &c.), kept a temperature a little below the boiling point of the most volatile to be isolated; the less volatile vapours are thereby condensed and fall back into the still, whilst the most volatile body passes on, and is condensed in a separate worm-tube. Thus in the diagram, Fig. 1, the vapour generated in the still *c* passes upwards through the vertical column, *a*, which is fitted internally with shelves, *b b b*, pierced with holes; the ascending vapour is here well scrubbed with the liquor already condensed; the vapour then passes through the condensers, *j j j j*, which are immersed in a tank, *k*, heated to the required temperature by means of a steam worm, *o o*: the condensed liquid runs back into the still through the pipes, *l l l l*, whilst the uncondensed vapour passes on to the worm, *n*, and is there condensed. (*a*, tower; *b b b*, shelves pierced with holes; *c*, still heated by a steam worm, *d*; *d d*, steam worm; *f*, cock for emptying still; *f' g*, manholes; *h*, thermometer for reading off the temperature of the vapour at the top of the tower; *i*, tube leading vapours from tower to condensers; *j j j j*,

condensers immersed in a tank of hot water, &c.; k, tank containing hot liquid; $l\ l\ l\ l$, reflex tubes for liquids condensed in j to pass back to the still; m, thermometer in tank; n, worm tube well cooled; $o\ o$, steam worm to heat tank k. Figs. 2 and 3 represent the arrangement of the perforated shelves, $b\ b\ b$, whereby the ascending vapour is "scrubbed" with the liquor already condensed. $b'b'$, sections of perforated shelves; $p\ p\ p\ p$, partition walls not reaching wholly across, but arranged so as to cause the vapour to travel horizontally; $q\ q\ q\ q$, pipes perforated with holes into which the vapour ascends; r, boss against which the vapour impinges; $s\ s$, overflow pipe through which the condensed liquid drops down into next lower compartment).

In the distillation of benzol, so as to separate approximately benzene, toluene, &c., the liquid to be distilled is heated by a steam worm, $d\ d'$, at about 2 atmospheres pressure; the tank, k, being kept at 60° to 70°, all toluene and higher homologues are condensed by the worms, $j\ j\ j\ j$, whilst the benzene vapour passes on to n. When all the benzene (or nearly all) has thus passed over, the tank, k, is heated to 100° to 105°, and the pressure of steam in the still increased to $3\frac{1}{2}$ atmospheres; a small quantity of toluene,

Fig. 2.

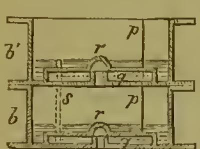
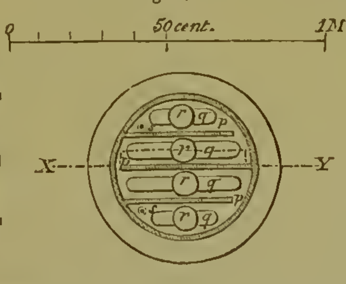


Fig. 3.



mixed with the residual benzene, now passes over to n, and in a short time commercially pure toluene only is obtained. Similarly when nearly all the toluene is separated, "xylene" and "cumene" may be similarly separated, the steam pressure on the still being raised to 6 or 7 atmospheres, and the tank, k, being heated to a few degrees below 138° and 165° respectively; for this purpose, a strong solution of ammonium nitrate is used in the tank.

From 100 litres of benzol, wholly distilling between 62° and 150°, the following quantities of distillates may be obtained by this apparatus (COUPIER):—

Nature of Distillate.	Litres condensed in n.	Boiling Point.
Mixture of benzene and lower boiling substances,	6	62°— 80°
Nearly pure benzene,	44	80°— 82°
Mixture of benzene and toluene,	6	82°—110°
Nearly pure toluene,	17	110°—112°
Mixture of toluene and xylene,	5	112°—137°
Nearly pure xylene,	9	137°—140°
Mixture of xylene and higher homologues,	5	140°—148°
" (?)	8	148°—150°
	100	

These figures may be represented graphically by the following diagram, where the ordinates are the boiling temperatures, and the abscissæ the bulks of the distillate (Fig. 4).

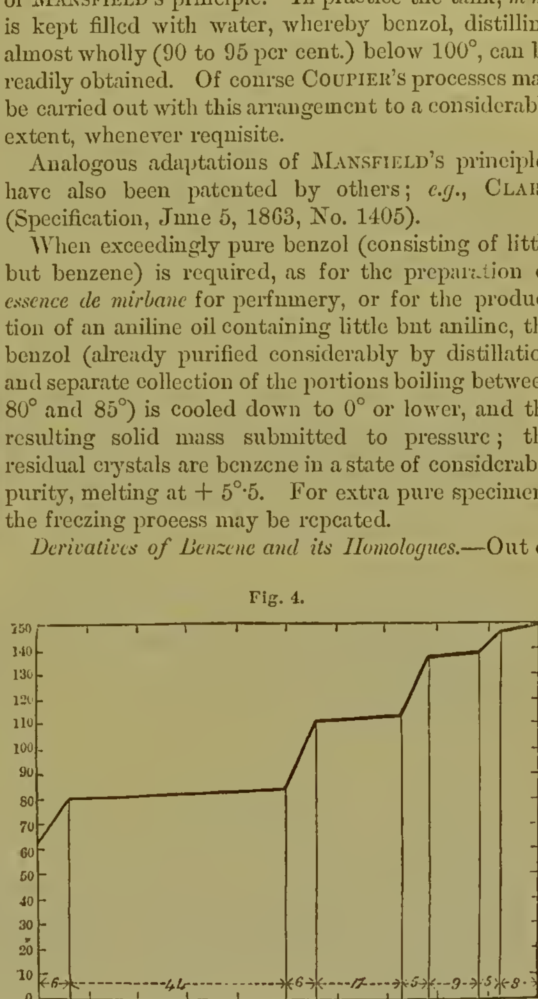
The benzol still, I., depicted Plate I., is an adaptation of MANSFIELD's principle. In practice the tank, $m\ m$, is kept filled with water, whereby benzol, distilling almost wholly (90 to 95 per cent.) below 100°, can be readily obtained. Of course COUPIER's processes may be carried out with this arrangement to a considerable extent, whenever requisite.

Analogous adaptations of MANSFIELD's principles have also been patented by others; *e.g.*, CLARK (Specification, June 5, 1863, No. 1405).

When exceedingly pure benzol (consisting of little but benzene) is required, as for the preparation of *essence de mirbane* for perfumery, or for the production of an aniline oil containing little but aniline, the benzol (already purified considerably by distillation and separate collection of the portions boiling between 80° and 85°) is cooled down to 0° or lower, and the resulting solid mass submitted to pressure; the residual crystals are benzene in a state of considerable purity, melting at + 5°·5. For extra pure specimens the freezing process may be repeated.

Derivatives of Benzene and its Homologues.—Out of

Fig. 4.



the enormous numbers of bodies of this nature, comparatively few have as yet met with industrial applications; of these many are naturally occurring products, and in many instances the agreeable odour they possess leads to their use in perfumery. Some few have a medicinal value; others, such as carbolic acid, meet with special applications on account of their peculiar properties. Descriptions of those derivatives that are employed in the arts and manufactures will be found under their special names.

By oxidation the benzene hydrocarbons usually give rise to acids; thus:—

Toluene.

$$2C_6H_5.CH_3 + 3O_2 = 2C_6H_5.CO_2H + 2H_2O$$

Dimethyl benzene.

$$C_6H_4\left\{\begin{matrix}CH_3\\CH_3\end{matrix}\right. + 3O_2 = C_6H_4\left\{\begin{matrix}CO_2H\\CO_2H\end{matrix}\right. + 2H_2O, \&c., \&c.$$

No industrial application is made of this kind of reaction, but a somewhat analogous change is utilized in the artificial production of benzoyl hydride, or oil of bitter almonds. When toluene is chlorinated, amongst other products there is found benzyl chloride, to which the formula $C_6H_5.CH_2Cl$ is applied. When this is treated with dilute nitric acid, or

better, lead nitrate, it becomes converted for the most part into benzoyl hydride; thus—

$$2CH_5.CH_2Cl + O_2 = 2C_6H_5.COH + 2HCl.$$

(*Vide* p. 351.)

One class of benzene derivatives, however, is of great commercial importance, viz., the bodies which result from the action of concentrated nitric acid on the hydrocarbons; mixtures of these products constitute the *nitrobenzol* of commerce, the source of aniline and the dyes thence derived (*q. v.*).

The formation of the main constituents of this commercial product may be exemplified by the following equation; small quantities of other derivatives (dinitro- trinitro- bodies, &c.) are also present.

$$C_6H_x\,(CH_3)_{6-x} + NO_2OH = HOH + C_6H_{x-1}\,(CH_3)_{6-x}\,(NO_2).$$

Thus the following bodies are present in commercial nitrobenzol:—

	Boiling Point.	
$X = 6$ Nitrobenzene $C_6H_5(NO_2)$	205—219	various observers.
$X = 5$ Para nitro-toluene......... $C_6H_4(CH_3)p(NO_2)$................	235—226	BEILSTEIN and KUHLBERG.
$X = 5$ Meta nitro-toluene........ $C_6H_4(CH_3)_m(NO^2)$................	222—223	do.
$X = 4$ Various nitro-xylenes.... $C_6H_3(CH_3)_2(NO_2)$................	near 240°	
$X = 3$ Various nitro-cumenes... $C_6H_2(CH_3)_3(NO_2)$................	250—265	

Ortho-nitro-toluene is also known, but its presence in nitrobenzol is as yet unproved; the various probable isomerides of nitroxylene and nitrocumene have not yet been thoroughly investigated.

Each one of these substances, when in conjunction with reducing agents, such as nascent hydrogen, undergoes the following reaction, thereby giving rise to the "aniline base" corresponding to the nitro compound employed:—

$$C_6H_{x-1}\,(CH_3)_{6-x}\,(NO_2) + 3H_2 = 2H_2O + C_6H_{x-1}\,(CH_3)_{6-x}\,(NH_2).$$

The aniline bases thus produced have been already discussed (*vide* ANILINE), and their mode of manufacture described; it only remains, therefore, to give the description of the processes employed in the commercial production of nitrobenzol, and of the general properties of the constituents of this body.

Nitrobenzene.—This body was discovered by MITSCHERLICH in 1834. When pure it forms a colourless liquid of odour resembling oil of bitter almonds, and of specific gravity 1·209 at 15° (MITSCHERLICH), 1·1866 at 14°·4 (KOPP); it boils at a temperature variously stated by different observers, *e.g.*, 205° (KEKULÉ), 213° (MITSCHERLICH), and 219° (KOPP); it solidifies to a crystalline mass between 0° and + 3°. It constitutes the main constituent of the *essence de mirbane* used in perfumery, which is prepared by the same processes as commercial nitrobenzol, only from nearly pure benzene (*vide* p. 349). This manufacture was first proposed by MANSFIELD, who patented the production of an artificial oil of almonds in 1847; in the succeeding year PELOUZE and COLAS commenced making it for this purpose in Paris; but the demand was small and the production limited, until the invention of aniline dyes called for the production of aniline on the large scale. It is slightly soluble in water (100 of water dissolve 0·18 parts of nitrobenzene), addition of common salt precipitates most of the oil thus taken up; dilute acids dissolve it somewhat more readily, whilst alcohol, ether, benzene, and its homologues dissolve it easily.

The higher homologues of nitrobenzene, viz., the *nitrotoluenes*, *nitroxylenes*, and *nitrocumenes*, exhibit, so far as they have been investigated, considerable resemblance to the parent body nitrobenzene; on nitration, toluene gives rise to para and meta nitrotoluene simultaneously, from which para and meta toluidine are respectively obtainable. Ortho-nitrotoluene has been obtained by BEILSTEIN and KUHLBERG by acting with alcoholic potash on nitroparacet-toluide, whereby a nitrotoluidine is obtained; on acting with nitrous acid on this compound a diazo-derivative results, which yields ortho-nitrotoluene on boiling with alcohol (meta-nitrotoluene is obtainable in the same way from the corresponding diazo-derivative of the nitrotoluidine resulting from the reduction of dinitrotoluene melting at 70°·5). These three isomerides may be thus contrasted.

	Para.	Meta.	Ortho.
At ordinary temperatures,..	Solid.	Liquid.	Liquid.
Melting point,............	54°	—	Solidifies in freezing mixture, and then melts at + 16°
Boiling point,............	235° to 236°	222° to 223°	230° to 231°
Specific gravity,..........	—	1·163 at 23°·5.	1·168 at 22°
Action of chromic acid,...	Readily oxidized, forming para-nitro-benzoic acid (nitro-dracylic acid), melting at 240°.	Scarcely any action, even after boiling for several days.	Readily oxidized to ortho-nitro-benzoic acid, melting at 140°.
Action of reducing agents,.	Forms para-toluidine, melting at 45°.	Forms meta-toluidine, not solidifying at —20°.	Forms ortho-toluidine, not solidifying at —13°.

The various nitroxylenes and nitrocumenes have not as yet been minutely examined; the nitroxylene obtained by nitrating methyl toluene or para-xylene (p. 343) boils at 240°; that from isoxylene or meta-xylene, at 237° to 239°, and solidifies in a freezing mixture, melting at + 2 (TAWILDARROW).

Nitrocumene, from the nitration of trimethyl benzene (pseudo cumene,) boils at 265°, and melts at 71° (FITTIG); that from mesitylene boils at a temperature between 240° and 250°, and melts at 41°. The nitrocumene present in commercial nitrobenzol is probably a mixture of these two bodies, and possibly of other isomerides also.

The existence of higher homologues of nitro-

cumene in commercial nitrobenzol has not yet been definitely proved.

In addition to the above-mentioned mono-nitro derivatives of benzene, more highly nitrated products are often present in commercial nitrobenzol to a greater or less extent, depending much on the way in which the manufacture is carried out. The following list exhibits the chief of them:—

Dinitrobenzene, melting point 80°, ...	$C_6H_4\left\{\begin{matrix}NO_2\\NO_2\end{matrix}\right.$
Dinitrotoluene, from nitration of toluene, melting point 71°, ...	$C_6H_3\left\{\begin{matrix}CH_3\\NO_2\\NO_2\end{matrix}\right.$
Dinitroxylene, from nitration of para-xylene. Two isomeric modifications are thus formed, one melting at 123°·5, one at 93°, ... Dinitro-isoxylene, from nitration of isoxylene (metaxylene), melting point 93°, ...	$C_6H_2\left\{\begin{matrix}CH_3\\CH_3\\NO_2\\NO_2\end{matrix}\right.$
Dinitrocumene, from nitration of pseudo cumene, ... Dinitro-mesitylene, from nitration of mesitylene, melting point 86°, ...	$C_6H\left\{\begin{matrix}CH_3\\CH_3\\CH_3\\NO_2\\NO_2\end{matrix}\right.$

On reduction, the bodies give rise, first, to *nitraniline*, $C_6H_4\left\{\begin{matrix}NO_2\\NH_2\end{matrix}\right.$, and its homologues; secondly, to phenylene diamine, $C_6H_4\left\{\begin{matrix}NH_2\\NH_2\end{matrix}\right.$, and its homologues. For the description of these derivatives and the properties of their various isomerides derived from other sources, and of the further nitro derivatives of benzene and its homologues (*e.g.*, trinitrobenzene, $C_6H_3(NO_2)_3$; trinitrotrimethyl benzene, $C_6(CH_3)_3(NO_2)_3$, &c., &c.), the reader is referred to the manuals and text-books of chemistry.

Chlorobenzene, C_6H_5Cl, and its higher homologues, have been proposed by POULAIN as a source of aniline colours (*vide* article ANILINE); these products are obtained by the action of chlorine in presence of iodine on benzene and its homologues: on nitration, chlorobenzene is obtained from a nitrochloro chlorobenzene, from which chloraniline is obtained by the usual process of reduction; similarly with the higher homologues.

Manufacture of Nitrobenzol.—The earliest methods employed in the production of nitrobenzol were only suitable for the manufacture of small quantities at a time; as the trade increased numerous accidents occurred, partly due to the impurity of the benzol used (benzol containing carbolic acid, &c., being attacked by nitric acid with explosive violence in some cases), partly to the poisonous nature of the nitrobenzol itself, which continually leaked from the earthenware vessels employed, and partly to the injurious action on the lungs of the workmen of the nitrous fumes evolved. The use of highly concentrated nitric acid, mixed with strong sulphuric acid, instead of the more dilute acid at first employed, permitted cast-iron vessels to be substituted for earthenware ones; and the improved processes adopted for the purification of the benzol used obviated the dangers arising from explosive action and from the evolution of corrosive gases, or at least reduced these dangers to an amount quite inconsiderable with due care and suitably constructed apparatus.

Essence de mirbane was at first fabricated by allowing benzene to drop slowly into a mixture of strong sulphuric acid and of ordinary nitric acid. The acids were mixed in a vessel placed in a tub of water, much heat being evolved by adding this comparatively dilute nitric acid to the sulphuric acid; the benzene was then allowed to drop in, with occasional stirring. The difficulty of regulating the action in this arrangement was considerable, and dangerous explosions often occurred, especially when considerable quantities of materials were used. The object of adding sulphuric acid is virtually to concentrate the nitric acid by uniting with the water set free in the reaction—

$$C_6H_6 + NO_2.H = H.OH + C_6H_5.NO_2.$$

Theoretically, there should be no evolution of lower oxides of nitrogen; but secondary reactions are often set up, and the oxidation of the impurities in the benzene used also gives rise to the production of nitrous gases.

By operating in this way, the nitric acid being in excess with reference to the benzene as the latter enters, considerable quantities of dinitrobenzene are formed; hence the process is now modified in this way, that the mixture of acids is allowed to drop into the benzene instead of *vice versa*, the nitric acid used being the strongest possible, *i.e.* the red "fuming acid" of commerce (nitric acid of specific gravity 1·4 or higher, containing lower oxides of nitrogen dissolved in it).

LAROQUE proposed the preparation of nitrobenzol by allowing the *vapours* of benzol and nitric acid to react on each other, each substance being distilled from a separate still, the vapours meeting in a common worm tube. This process does not seem to have met with much favour; but MANSFIELD's plan of allowing *liquid* benzol and acid to trickle together into a funnel placed at the top of a worm tube has been adopted with success, the rate of flowing of the two streams being suitably adjusted by stopcocks, so that about 3 parts of acid to 2 of benzol are allowed to mix. Instead of a worm tube, a vertical glass column filled with balls or fragments of glass has been employed, so as to effect an intimate mixture of the benzol and acid by gravitation, by using these substances in the following proportions:—

Benzol, ...	10 kilos.
Nitric acid of specific gravity 1·5, ...	12 "

Two liquids drop out at the bottom of the tube, and collect in a suitable tank placed to receive them (a ventilator or chimney being attached to the tank to allow of the escape of nitrous fumes, this chimney being cooled by a stream of water applied to its exterior, or interior, if necessary, so as to condense nitrous acid vapours should they escape). Of these liquids one is nitrobenzol, the other nitric acid of specific gravity 1·302, sufficiently strong for many industrial applications (GIRARD and DE LAIRE).

The nitrous vapours evolved in the manufacture

of nitrobenzol have been utilized for vitriol making; spent or dilute nitric acid, washings, &c., may be converted into nitrate of lime by saturation with chalk or marble, evaporated to dryness, and distilled with strong sulphuric acid so as to regenerate the strong nitric acid required.

Nitrate of soda, mixed with sulphuric acid, has been employed by PERKIN in lieu of nitric acid, or a mixture of nitric and sulphuric acids. The required amount of nitrate of soda is introduced into a horizontal cylinder of cast iron, furnished with a manhole covered by a luted door, and with two tubulures at the top; to the one is attached the condensing worm, through the other are introduced from time to time benzol and sulphuric acid; explosive action is very apt to occur with this arrangement.

The method now employed in the principal factories is the one first used, with the modification that the mixture of acids is made to drop into the benzene instead of *vice versa*. A cylindrical cast-iron vessel of 30 to 40 cubic feet capacity is provided with an agitator, an exit tube for nitrous vapours (cooled externally by cold water so as to condense nitric acid vapour should that escape), and a syphon S-shaped delivery tube, whereby the acid is allowed to run in from a reservoir by gravitation. The benzol to be nitrated is introduced into the cylinder, the agitator is revolved by machinery, and the mixture of acids allowed to trickle in slowly. It is sometimes necessary to warm the cylinder slightly to start the action, or to cool it to diminish the activity. This can be effected by means of a jacket surrounding the lower part of the cylinder, into which hot or cold water or steam can be let at pleasure. With a uniform system

Fig. 5.

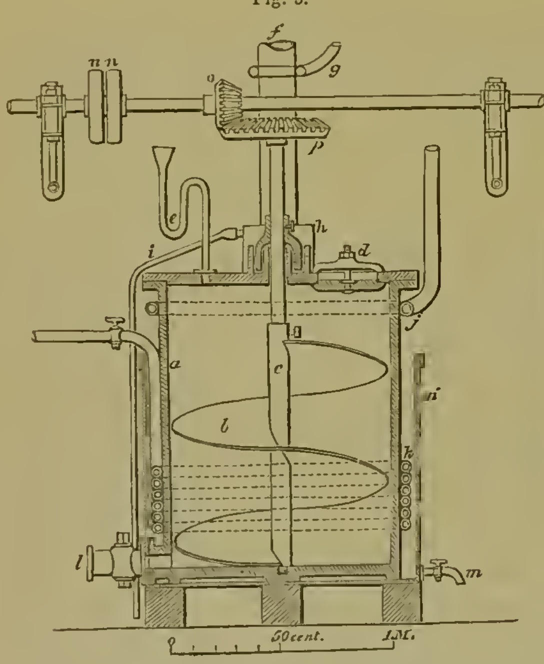
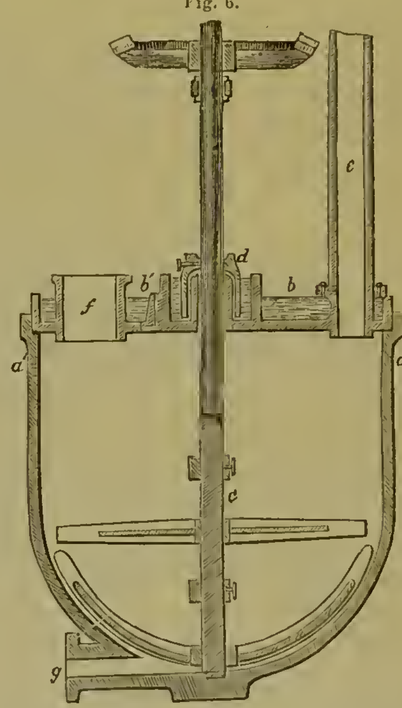


Fig. 6.



of working this jacket can be dispensed with, the action being moderated, if proceeding too violently, by cutting off the supply of acid until the action is diminished sufficiently.

The following diagram illustrates the nature of the arrangement (GIRARD and DE LAIRE, "Traite des Derivés de la Houille," Paris, 1873). Fig. 5: *a*, cast-iron cylinder; *b*, helical agitator; *c*, axle of agitator; *d*, manhole for introduction of solid materials; *e*, syphon tube for introduction of liquid materials; *f*, escape-pipe for gaseous and vaporous products; *g*, circular water-pipe, whereby a thin sheet of water is made to flow down the exterior of the escape-pipe *f*; *h i*, reservoir and overflow pipe for descending stream of water; *j*, circular water-pipe, whereby a thin sheet of water is made to flow down the exterior of the cylinder *a*; *k*, worm tube capable of being used for steam, hot water, or cold water as required, to warm or cool the cylinder *a*; *l*, emptying cock; *m*, emptying cock, for emptying jacket *m′*; *m′*, water jacket; *n n o p*, pulleys and cog wheels for communicating motion to agitator.

Fig. 6, and BENZOL, Plate I., Fig. 2, illustrate another form of arrangement. *a* is a cylindrical vessel with hemispherical bottom made of cast iron; *b b*, dish-shaped lid holding water, whereby vapours are partially condensed; *c*, agitator spindle; *d*, water lute fixed to agitator; *e*, exit pipe for vapours; *f*, manhole for introduction of materials; *g*, emptying pipe; *m*, shaft communicating motion to agitators. Several stills are arranged side by side as indicated in Plate I., Fig. 2.

When the nitration is completed, the agitator is stopped; after standing some time the acid is run off by a tap at the bottom of the cylinder, and the nitrobenzol washed in the nitrating cylinder by intro-

ducing water, revolving the agitator, then allowing to stand, and running off the acid water, and repeating the operation. The acid being apt to attack the metal of the cylinder, &c., milk of lime or solution of caustic soda is usually employed in the first washing, water being used for the subsequent ones.

In a large factory it is better to wash all nitrobenzene at once in a separate vessel. A cast-iron tank (Fig. 7) of some 6 or 7 cubic yards capacity is so arranged at the basement, that the nitro-benzol and acids from all the nitrating cylinders can be run into it simultaneously. The tank is partially exhausted of air, so that the nitrous fumes are sucked into it along with the liquids. The acids are then drawn off by taps at the bottom of the tank, and a jet of water with which milk of lime is mixed allowed to flow in through a serpentine tube (Fig. 8), pierced with holes in such a way that a circular movement of the contents of the tank is set up together with an upward current from the bottom; the small amount of residual acid is thus immediately neutralized; the aqueous liquid is then run off, and several washings with pure water given.

Fig. 7.

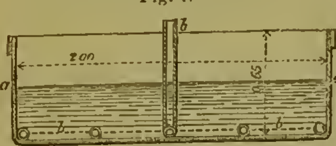
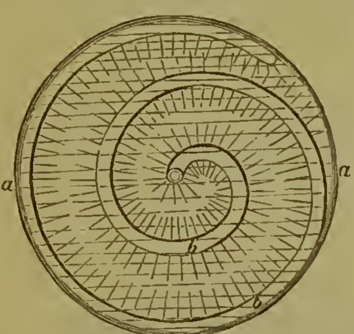


Fig. 8.



When the manufacture of the nitrobenzol has been properly carried out, the product thus obtained amounts to 135–140 per cent of the benzol used, and can be run immediately into the aniline stills. The material made by the older processes, however, frequently contained unaltered benzol, which was removed by distilling in retorts heated by a water-bath or a steam jacket. The quantity of dinitrobenzol present in well made nitrobenzol is not great; but the products of the older processes frequently required to be distilled so as to separate the more volatile aniline-producing constituents from the less volatile dinitro bodies, &c. When required (as in the preparation of *essence de mirbane*), this is now effected by blowing a jet of steam (superheated if necessary) through the nitrobenzol contained in a large still, the worm tube carrying the steam being pierced with holes, and reaching to the bottom of the still. With a copper still of 1500 to 2000 litres capacity, and steam at 5 atmospheres, 150 to 200 kilos. of nitrobenzol can be distilled per hour (GIRARD and DE LAIRE). Formerly the distillation was carried on in small retorts heated over a free fire or by hot air. As the distillate is apt to be slightly acid, it is well to add a little chalk.

The preparation of *essence de mirbane* is identical with that of the nitrobenzol of the aniline maker, except that the product is usually distilled with steam, and that nearly pure benzene is used.

The manufacture, in this way, of so-called artificial oil of almonds dates from 1847, when it was first prepared by MANSFIELD. Of late years the actual oil of bitter almonds (benzoyl hydride) has been prepared by the action of certain oxidizing agents on benzyl chloride as follows:—

Manufacture of Benzoyl Hydride, Oil of Bitter Almonds, Benzaldine, Benzoic Aldehyde (C_7H_6O):—Toluene is heated in a vessel furnished with a cohobator and a distilling worm, in such a way that either can be connected or disconnected at will. The cohobator being coupled on, the toluene is heated to the boiling point and a current of chlorine passed through the vapour emitted. This is best regulated by means of an aspirator attached to the cohobator, two WOLFFE'S bottles being interposed, the first containing water, to complete the arresting of toluene, &c., the second caustic soda ley, to retain chlorine.

If chlorine acts on *cold* toluene, chlorotoluene, $C_6H_4\left\{\begin{matrix}CH_3\\Cl\end{matrix}\right.$, chiefly results; but at the boiling temperature benzyl-chloride is formed, the two reactions being—

$$\text{(Cold.)}\quad C_6H_5.CH_3 + Cl_2 = C_6H_4\left\{\begin{matrix}CH_3\\Cl\end{matrix}\right. + HCl$$

$$\text{(Hot.)}\quad C_6H_5CH_3 + Cl_2 = C_6H_5.CH_2Cl + HCl$$

The two products, though possessing the same percentage composition, are wholly different, physically and chemically; thus, their boiling points are 20° C. apart, and the former is incapable of forming artificial oil of almonds.

When a thermometer indicates that the liquid in the still boils at 140° to 145° the chlorine current is discontinued, the cohobator disconnected, and the contents of the still distilled over. The portion boiling below 170° is chiefly unaltered toluene, and is used over again; that which passes at 170° to 200° is rectified, and the portion boiling at 174° to 176° collected apart.

Instead of benzyl chloride, benzyl bromide may be used. This is prepared in just the same way, save that bromine vapour is used instead of chlorine gas, the portion collected during the final rectification being that passing at 195° to 205°.

LAUTH and GRIMAUX convert benzyl chloride into benzoyl hydride thus; $1\frac{1}{4}$ kilo. of lead acetate, 10 litres of water, and 1 kilo. of benzyl chloride, are heated together in a cohobator from three to four hours, a current of carbon dioxide being passed through the apparatus (to displace air, the oxygen of which would convert the bitter almond oil into benzoic acid). The contents of the retort are then half distilled over; the whole of the benzoyl hydride then passes along with water, on which it floats; the oily liquid is decanted and heated with sodium acid sulphite, with which it combines; the crystalline compound is washed with alcohol and decomposed by addition of an alkali. The yield is about three quarters of the theoretical amount.

BISMUTH.—*Etain de Glace*, French; *Wismuth*, German: symbol, Bi; atomic weight, 208 (SCHNEIDER), 210 (DUMAS).—This comparatively rare metal has been known for about three centuries, GEORGE AGRICOLA having described it in 1546 as a metal "somewhat different from lead." In nature, bismuth occurs principally in the metallic state, generally associated with the ores of cobalt, nickel, copper, and silver; and in combination as *Bismuth glance* or *bismuthine*, Bi_2S_3; *bismuth ochre*, Bi_2O_3; *bismuthite*, Bi_23CO_3; *bismuth blende*, Bi_23SiO_3; *cupreous bismuth*, $3(Cu_2S)Bi_2S_3$; and combined with copper, silver, lead, cobalt, and nickel, in several other more complex minerals, among which may be mentioned *aciculite* or *needle ore*, *kobellite*, and *bismuthic silver*. It is found with tellurium in *tetradymite*, and with vanadium in *pucherite*.

Bismuth ores occur most plentifully in Saxony, Bohemia, and Transylvania; but they are also found in Norway, Sweden, and the United States, and in England in Cornwall and Cumberland, and Stirlingshire in Scotland.

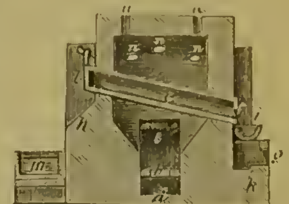
Metallurgy.—Bismuth is almost wholly obtained from ores containing the native metal, its extraction from which is rendered exceedingly simple by its ready fusibility. The ancient method was to fire a mixture of ore and fuel, when the metal melted and subsided to the bottom of the heap. At Schneeberg, in Saxony, where the greater part of the bismuth in the market is produced, it is obtained from cobalt ores previously to their employment in the manufacture of smalt.

The operation is conducted in cast-iron retorts placed obliquely, and heated by a furnace beneath them. When the bismuth of the ore with which these retorts are charged is fused, it flows down into an appropriate receiver, leaving behind it the siliceous and other impurities. The furnace used at Schneeberg is represented in the annexed Figs. 1, 2, 3; the first of which is a plan; the second a section at A B, Fig. 1; and the third a front elevation at k k, Fig. 1.

Fig. 1.

In the plan—Fig. 1—the fire-door is represented by a, the grate by b, and the cylindrical retorts by c c c, which incline towards the iron pans, i i i, where the fused metal is collected. A wall, k k, supports the pans; and to prevent the metal from forming an alloy with the latter, and also to obviate its oxidation, it is customary to throw a little charcoal powder into each. The slag remaining in the pipes after the metal is separated from it, is drawn off into a tank of cold water situated at m. In doing this the heated matter does not splash at once into the water, but falls gently down the declivity, h. This arrangement is shown in elevation—Fig. 2—which is a section of the preceding, the same objects being distinguished by the foregoing letters. The pipes, c c, are closed at the depressed end by clay plates, f, with the exception of a small opening through which the fused metal issues to the receivers, c. A stout cast-iron door-plate, l, secures them at the other end.

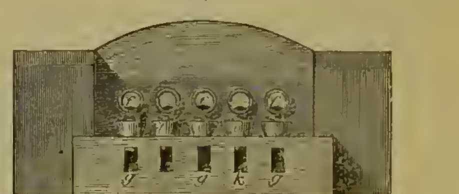
Fig. 2.



The retorts are heated by the fire, e, with the assistance of flues passing from it round each severally, as seen in Fig. 2 and Fig. 3, at g g. The draught of the furnace is increased at will by opening the holes shown at n n, Fig. 2, placed between each pair of retorts.

The ore is prepared by breaking it up and removing the very impure portions; this being effected, about half a hundredweight is introduced into each of the retorts, the door-plates, l, made secure, and the fire stirred up to communicate the required degree of heat. The charge should only be about three-eighths of the capacity of the retorts, in order that it may be conveniently stirred.

Fig. 3.



After the application of the heat for ten minutes the metal begins to run out by the small space in the clay plate, f, at the end; and as soon as the flow slackens the contents of the retort are stirred with a rake till the whole of the metal is obtained, which is usually the case in half an hour. The slag, deprived of all the metal, is then raked out of the retorts into the water tank in front, and replaced by a fresh charge. When the pans, i i i, are nearly full, the fused metal is ladled out and cast into bars, weighing each from 20 to 50 lbs.

At Schneeberg, where about 10,000 pounds of bismuth are annually produced, wood is the fuel employed, 50 cubic feet of which is sufficient to work off a ton of ore.

At Joachimsthal, in Bohemia, a process devised by VOGEL, for extracting bismuth from other ores than those containing the native metal, has latterly been employed. The ore is powdered, mixed with 28 per cent. of small scrap iron, 15 to 50 per cent. of soda ash (according to the amount of silica in the ore), 5 per cent. of lime, and 5 per cent. of fluor spar. Crucibles, 2 feet in height and 16 inches in diameter, are each charged with about 1 cwt. of this mixture, closed, and strongly heated till the mass

becomes pasty. The contents are then well stirred to effect complete mixture, reheated till perfectly liquid, and then ladled into conical moulds. The bismuth, together with the cobalt speiss, subsides to the bottom, and on cooling is separated from the speiss, which, however, still retains about 2 per cent. of bismuth.

Refining.—The bismuth obtained by these methods is contaminated with arsenic, iron, copper, and silver.

The greater part of the arsenic may be removed by strongly heating the bismuth in a crucible under a layer of charcoal, when the arsenic passes off in vapour. TAMM recommends immersing strips of iron in bismuth fused under a layer of borax. He states that the arsenic unites with the iron, and on cooling the still fluid bismuth may be decanted from the iron arsenide, which solidifies more rapidly.

Copper, according to the same authority, may be removed by treating the fused metal with one-sixteenth part of a mixture of 8 parts potassium cyanide, with 3 parts of sulphur, the crucible being kept covered during the deflagration that ensues. The metal is then well stirred and the flux allowed to set, upon which the metal is poured out.

Antimony may be removed by heating the bismuth with about 3 parts of teroxide of bismuth for each part of antimony present, the antimony being converted into oxide, while the oxide of bismuth is at the same time reduced to the metallic state.

Bismuth, when required pure, may be prepared by dissolving ordinary bismuth in just sufficient nitric acid, filtering from arseniate of bismuth and other insoluble impurities, and then largely diluting with water, which precipitates the bismuth as basic nitrate. This precipitate is washed and digested with potash, after which it is again washed, and finally reduced to the metallic state by heating with charcoal in a crucible.

Properties.—Bismuth is a white metal with a tinge of red. It crystallizes in rhombohedra closely resembling cubes, which are obtained artificially in the following manner:—A large quantity of bismuth is fused in a crucible; while still red hot the crucible is embedded in hot sand, so as to cool slowly. When part of the metal has solidified and there is a firm crust on the surface, two holes are made in the crust with a red-hot rod, and through one of them the metal still remaining liquid is poured off; the other hole serves to admit air. Upon breaking the crust the solidified portion will be found beautifully crystallized, the crystals having an iridescent tarnish, caused by contact with the air while yet hot. Bismuth is exceedingly brittle, and it has so little tenacity that a rod one-tenth of an inch in diameter only sustains 40 lbs.

Pure bismuth melts at 264° C. (607° Fahr.); at a high temperature it volatilizes, and may, though with great difficulty, be distilled. Its specific gravity is variously given at from 9·6 to 9·8, the higher number being probably the more correct. When subjected to pressure, instead of being rendered denser, it is reduced in specific gravity. Thus MARCHAND and SCHEERER, by submitting a cylinder of the metal to powerful pressure, succeeded in reducing its specific gravity from 9·799 to 9·556. It is the most diamagnetic substance known. Its diamagnetic repulsion being nevertheless only $\frac{1}{2500000}$ of the attraction of an equal mass of iron.—(WEBER.)

Bismuth, like water, expands on solidification; but while water expands on cooling from 4° C. to the freezing point, bismuth only expands at the moment of solidification.—(TRIBE.) When fused it can be cooled several degrees below its melting point without solidifying, but the instant that solidification begins, the temperature rises to the fusing point, and remains so till the whole has solidified.—(URE.)

Bismuth is not affected by dry air, and is only slightly acted on by a moist atmosphere; its vapour decomposes steam (REGNAULT), and the solid metal at a white heat decomposes water. When strongly heated in the air, it burns with a bluish flame, evolving light yellow fumes of bismuthous oxide, Bi_2O_3. In chlorine gas, divided bismuth takes fire, forming bismuthous chloride, $BiCl_3$. It is attacked with difficulty by hydrochloric and sulphuric acids, but is readily dissolved by slightly dilute nitric or nitro-hydrochloric acids, forming bismuthous nitrate and chloride respectively. It also enters into combination with most of the non-metallic elements, and with many inorganic negative radicles.

Uses in the Arts.—Bismuth is too brittle to be useful by itself, and hence is chiefly employed in the arts for alloying with other metals, generally lead and tin, in order to communicate to the resulting alloy, either fusibility or the property of expansion on solidification above referred to. In bell-founding, bismuth is of considerable value, its alloy with tin being very sonorous.

Bismuth is sometimes employed in stereotype metal to communicate its expansive property, which causes the alloy to take a very exact impression, and for the same reason it is used by die sinkers in the fusible metal employed to test the accuracy and finish of a die.

Fusible metal is an alloy of bismuth, tin, and lead. Thus, an alloy of 8 parts bismuth, 5 of lead, and 3 of tin melts at 202° Fahr.; and another, consisting of 2 parts bismuth, 1 of lead, and 1 of tin, liquefies at 200°·75 Fahr.—(ROSE.) Both these alloys are liquid in boiling water.

These fusible metals are rendered still more fusible by the addition of small quantities of mercury; such alloys are serviceable for taking casts of anatomical preparations.

The soft solder employed by pewterers consists of 1 part bismuth, 2 of tin, and 1 of lead; and the same composition has been proposed as a bath for tempering steel instruments, and has also been used in making the cake moulds for fancy toilet soaps.

An alloy for electrotype moulds is composed of 8 parts bismuth, 8 lead, and 3 tin. It melts at 228° Fahr. It is allowed to cool till it acquires a pasty consistency, and the warmed medal, or other article, pressed upon it and kept under pressure till cold.

If 2 parts of hot mercury be added to 1 part of

fused bismuth, a pasty amalgam is obtained, which after a time becomes granular, hard, and partly crystalline. Since a small quantity of bismuth only slightly diminishes the fluidity of mercury, it is occasionally used to adulterate the latter. This fraud may be detected by shaking the mercury with air, when a black powder separates.—(GMELIN.)

Bismuth and silver, when fused together in equal proportions, form a bismuth-coloured alloy. The silver may be extracted by cupellation, in the same manner as from argentiferous lead. Gold may also be extracted from its alloy with bismuth by cupellation.

Platinum and also palladium readily alloy with bismuth; 1 part of platinum or 2 parts of palladium form severally with 2 parts of bismuth, grey, brittle, fusible alloys.

Bismuth when alloyed with copper renders the copper harder, but at the same time brittle: 4 parts of bismuth and 1 of copper form an alloy having the red colour of copper and the crystalline texture of bismuth.

If a small quantity of bismuth be added to lead, it makes the latter tougher without becoming brittle. Equal weights of each give an alloy which resembles bismuth in all its properties, being of red tint, brittle, and laminar.

Oxides.—Four oxides are known, viz.:—The dioxide, Bi_2O_2; bismuthous oxide, or the trioxide, Bi_2O_3; tetroxide, Bi_2O_4; and bismuthic oxide, or the pentoxide, Bi_2O_5.

Bismuthous oxide, or the trioxide (Bi_2O_3) is the most important of these, and the only one which has received any industrial application. It occurs in nature as bismuth-ochre, associated with oxide of iron, carbonic acid, and water, at Schneeberg and Joachimsthal, and with gold in Siberia. It may be readily prepared by heating the neutral or basic nitrate until nitric fumes cease to be evolved. When pure, this oxide is of a straw yellow colour; at a red heat it fuses to an opaque glass, which, while hot, is dark brown or black, but on cooling again becomes yellow. In the arts it is used for fixing the gilding on porcelains, since at a high temperature it acts as a powerful flux towards siliceous matters. It is also employed to destroy the colours which would be given by many substances used as fluxes.

Hydrated bismuthous oxide (Bi_2O_3,H_2O) forms as a white precipitate, when an alkali is mixed with a solution of any bismuthous salt, and as a white powder, when the basic nitrate or chloride is triturated with an alkali. When boiled with potash, it is converted into the yellow oxide through loss of its water of hydration. Heated with an alkaline solution of metallic sulphides, it converts them into the corresponding oxides.

The oxide and hydrate when treated with acids form bismuthous salts, of the general formula Bi_2R_3, R being univalent.

Bismuthous salts, with the exception of the yellow chromate, are white or colourless; most of those which contain oxygen are non-volatile, and decompose at a red heat. The chloride is, however, volatile. The neutral salts redden litmus paper, and are decomposed by a large quantity of water.

Nitrates.—Ternitrate, $Bi(NO_3)_3,5H_2O$. To prepare this salt the metal is dissolved in nitric acid with the aid of heat, and the solution concentrated by evaporation; on cooling it deposits in deliquescent transparent prisms. The crystals dissolve easily in dilute nitric acid, and on mixing this solution with water an insoluble basic nitrate precipitates, an acid salt remaining in solution.

Basic Nitrate or Trinitrate of Bismuth (*Bismuthum Album, Magistery of Bismuth, Flake White*). This compound is formed in the manner just mentioned, but to obtain the maximum yield, it is recommended to add 24 parts of hot water for each part of ternitrate; by this treatment 45 per cent. of the basic nitrate is obtained. Too much water should not be used in washing the precipitate, as it is rendered more basic by this treatment. The filtered liquid from the precipitate may be evaporated to dryness, or nearly so, and again decomposed by addition of water, when a further quantity of the basic salt is obtained. The washings from the first precipitation may be used for decomposing this second quantity. The purified metal must be used in the first instance if a pure product be desired, since the subnitrate is liable to contain arsenic and other impurities if this precaution be not taken.

Basic nitrate of bismuth thus obtained is a pearly white powder of a loose texture, presenting the appearance of crystalline scales under the microscope. Prepared from acid solutions with but little water it has a silky lustre, and the crystals are acicular. The salt manifests an acid reaction with litmus. It varies to some extent in composition, according to the temperature and the quantity of the water employed in its preparation, but it agrees pretty closely with the formula $Bi(NO_3)_3,Bi_2O_3,3H_2O$.

Oxychloride of bismuth may be prepared by adding water to a solution of the chloride, or by pouring a solution of ternitrate into a solution of common salt. It is used as a paint, and is known as *pearl white*.

Basic nitrate of bismuth has been advantageously employed in medicine. It is administered principally in affections of the stomach which are unaccompanied by any organic disease. It has been particularly prescribed to relieve gastrodynia and cramp of the stomach, to allay sickness and vomiting, and as a cure for pyrosis. Dr. PEREIRA gave it in the form of powder in conjunction with hydrocyanic acid mixture, and remarked that the patient seldom failed to obtain benefit from its use. Dr. THEOPHILUS THOMSON recommends it in doses of 5 grains, usually combined with 3 of gum arabic and 2 of magnesia, given every four or six hours in the diarrhœa accompanying phthisis. He thinks that both for efficacy and safety it surpasses our most approved remedies for that complaint. It has also been administered in intermittent fever and spasmodic asthma. HAHNEMANN directed a portion of it to be introduced into a hollow tooth to allay tooth-

ache. It was also used with advantage by Dr. PEREIRA, in the form of ointment applied to the *septum nasi* in ulceration of that part, and as a local remedy in chronic skin diseases.

In small doses it acts as an astringent, diminishing the secretion; but in large doses it is undoubtedly poisonous. It disorders the digestive organs, causing pain, vomiting, and purging, sometimes affecting the nervous system, producing giddiness, insensibility, cramp of the extremities, and even death.

Upon the lower animals it acts as a local irritant and caustic poison, and appears to exercise a specific influence over the lungs and nervous system.

It was formerly extensively employed as a cosmetic; but even here its use is dangerous, since when thus employed it produces spasmodic trembling of the face, commonly ending in paralysis.

Detection and Estimation.—Bismuth in solution is thus characterized:—

Sulphuretted hydrogen, in slightly acid or in alkaline solutions, throws down the black tersulphide.

Alkalies precipitate white bismuthous hydrate, insoluble in excess of the precipitant.

Potassium chromate throws down the yellow chromate, soluble in nitric acid and insoluble in potash.

Soluble sulphates produce no precipitate, which fact, in conjunction with the insolubility of the hydrate and chromate in potash, distinguishes bismuth from lead.

Water throws down a white basic salt in solutions of the chloride and nitrate, unless a large quantity of free acid be present. Where such is the case, or where the solution is very dilute, it is evaporated nearly to dryness previously to the addition of water; and if sulphuric acid be present, some sodium or ammonium chloride should be added. The basic salt being insoluble in tartaric acid, distinguishes it from antimony. This reaction with water is very characteristic. Before the blow-pipe, bismuth, with reducing agents on charcoal, gives a brittle metallic bead and a yellow incrustation.

Estimation.—When bismuth has to be estimated in those of its compounds which are free from admixture with other metals, the body is brought into the state of nitrate by acting on it with nitric acid, diluting the solution with water, heating almost to ebullition, and precipitating with carbonate of ammonia. In presence of hydrochloric acid the precipitate thus produced would contain some oxychloride, which on ignition would decompose, and part of the bismuth volatilize as chloride. In such a case the bismuth is first precipitated from the acid solution with sulphuretted hydrogen, and the tersulphide washed, removed while moist, together with the filter, to a beaker glass, and converted into nitrate by means of nitric acid. The end of the decomposition is indicated by the separated sulphur assuming a yellow colour. The remains of the filter paper are then filtered off, after addition of dilute nitric acid, and the filter well washed. The filtrate and washings are then mixed, and the bismuth precipitated with ammonium carbonate, the solution being heated as above mentioned. The precipitate is to be collected in a filter, washed with water, dried, transferred as much as possible from the paper to a porcelain crucible, and ignited. The filter is then burned separately, and the ash added to the oxide in the crucible and weighed. If highly ignited the oxide fuses, but does not decompose. As the teroxide contains 89·6 per cent. of metal, the amount of bismuth may easily be calculated. Bismuth being usually found associated with other metals—generally lead, silver, copper, arsenic, and iron—it may be interesting to give the process whereby the quantity of bismuth is ascertained in mixtures of these metals. The method also serves to detect adulteration in the preparations of bismuth, particularly when compounds of those metals are used.

The ore or compound is treated with nitric acid till dissolved, and this solution filtered and diluted with water; the washings of the residue, if any, are added, and a stream of sulphuretted hydrogen passed through it as long as a precipitate is produced. The vessel is then gently heated upon the sand-bath till the whole of the sulphides fall down; these are filtered and washed with water impregnated with sulphuretted hydrogen. The substance upon the paper is next digested with a strong solution of sulphide of potassium, which dissolves the sulphide of arsenic, leaving the sulphides of lead, silver, copper, and bismuth, which are separated from this solution by filtration and washing. These sulphides are then dissolved in nitric acid, the solution thus produced largely diluted, and the silver precipitated by hydrochloric acid. When the silver chloride has subsided, it is filtered, and the filtrate and washings evaporated with excess of sulphuric acid till the latter begins to be evolved. Sulphate of lead is thus formed, which is removed by filtering rapidly while hot, and washing the precipitate with water acidulated with sulphuric acid. The filtered solution now contains copper and bismuth. To separate the latter mix the diluted solution with carbonate of soda, in slight excess, add solution of cyanide of potassium, heat gently for some time, filter, and wash. The compound of bismuth on the filter contains some alkali, to remove which it is dissolved in nitric acid and reprecipitated by ammonium carbonate, as above directed. The precipitated bismuth is then treated in the same manner as before.

The quantity of each of the other constituents may be ascertained by weighing the precipitates already procured in the case of lead or silver. By adding ammonia to the filtrate containing the iron this body is thrown down as sesquioxide, which may be collected, dried, ignited, and weighed. The copper in solution, after the precipitation of bismuth, is ascertained by evaporation with strong sulphuric acid, to decompose the cuprocyanide of potassium, after which the copper may be thrown down by addition of caustic potash in excess and boiling. The black precipitate, consisting of oxide of copper, is well washed with boiling water, dried, separated from the filter, ignited, and weighed. This gives the amount of oxide of copper.

BITUMEN.—ASPHALT, MINERAL PITCH.—*Bitume*, *Asphalte*, French; *Bergpech*, *Erdpech*, German; *Asphaltum*, Latin.—Bitumen is a name used to denote various inflammable substances, consisting for the most part of hydrocarbon, of a strong smell and of different consistences, which are found in the earth.

There are several varieties, most of which pass into each other, proceeding from naphtha, the most fluid, to asphalt, which is sometimes too hard to be scratched by the nail. The most important forms are:—

Naphtha, or rock oil, a colourless liquid of the specific gravity 0·7 to 0·8.

Petroleum, a dark coloured liquid containing much naphtha.

Mineral tar, or *Maltha*, a viscous fluid.

Asphalt, a black or brown black brittle resinous substance, breaking with a smooth conchoidal fracture. Besides these there are various forms of mineral ozocerite, or ozokerit, Urpethite from the Urpeth colliery, and Hatchettite from Merthyr Tydville, which are various forms of mineral tallow.

Extensive magazines of bitumen are found in many parts of the world. It is sometimes found on the surface, exuding from the secondary or alluvial strata, where it is generally met with; but it is never found in the primary or older formation. The manner in which natural bitumen was formed is unknown, but it is supposed to be the result of the action of heat and moisture on organic substances which have been buried in the earth at a bygone period. This heat, when exerted upon such matters out of contact with air, would, as is well known in the laboratory, effect a decomposition analogous to destructive distillation, but different, inasmuch as that the pressure exerted at the same time would effect the liquefaction or solidification of many of the gaseous products evolved in the process. It is believed that a great deal of bitumen is formed from coal or lignite. Sulphuric acid by the aid of heat decomposes organic bodies, and gives rise to compounds, often bituminous, and very similar to the natural product.

The largest bituminous deposits in the world are those of the Dead Sea in Judea, and the Pitch or Tar Lake in Trinidad. Besides these extensive formations, bitumen is found in many other parts of the world; namely, as *mineral oil*, in Persia, the Caucasus, Burmah, the West Indies, and North America. And in smaller quantities in Italy, Bavaria, Hanover, China, and India. As asphalt and its congeners bitumen is met with in considerable quantities at Hatten, Bechelbronn, and Lobsann in Alsace, on the Lower Rhine; in France, at Parc and Pyrimont, near Seyssel on the Rhone, in the department of Ain; at Bastennes and Dax, department of Landes; in the departments of Auvergne, North, and at Val de Travers, Neufchatel, impregnating a bed in the cretaceous formation, and serving as a cement to the rock, which is used for building and paving, &c. Considerable quantities are found in South America, particularly at Coxitambo in Peru; in the islands of Cuba, Barbadoes, and in many parts of the West Indies; it is likewise found in Albania; near Naples, in Italy; in Persia, and in various other parts of the world.

In England very little bitumen, comparatively speaking, has been met with. It is produced at the coal mines of Hurlet near Paisley, where it incloses crystals of calcareous spar, and at the Odin mines in Derbyshire. The peat cut on Downholland Moss, near Ormskirk, Lancashire, has been found strongly impregnated with it. Considerable quantities of bituminous limestone are found in East Lothian, in Scotland.

These deposits are more fully described in the article Petroleum. The fluid and colourless kinds of bitumen are called naphthas, from the oriental word *nafata*, signifying to exude or pour out, as this curious liquid does, into the water of pits worked on the shores of the Caspian Sea. Viscid petroleum, or rock oil, seems to be liquefied asphalt, the solution being naphtha, or some analogous hydrocarbon. Petroleum chiefly flows from beds associated with coal strata. Until recently the Burman empire furnished the largest quantity of crude naphtha, but of late years the oil from the Pennsylvanian wells has almost entirely replaced Burmese petroleum.

A sandy loam, deposited upon alternate layers of siliceous and argillaceous matter, resting upon a bed of coal, are the geological characteristics of the district in which petroleum is met with. The clayey bed in contact with the strata of coal, which is of a bluish colour, contains the volatile fluid; and by sinking a shaft to some depth in this strata, the fluid, or rock oil, as it is termed, flows into it with sometimes no admixture of water.

Petroleum is also obtained in considerable quantity from the district of Baku, near the Caspian Sea. This locality is famed for its inextinguishable fires, which have continued burning for ages. They are occasioned by the ignition of the inflammable vapour exhaled from the soil, which is surcharged with the naphtha.

The bitumen of the Dead Sea, and that of the Tar Lake of Trinidad, as well as the viscid varieties of this country, and of many other parts, such as those of Bechelbronn in Alsace, &c., are apparently produced by the oxidation of liquid petroleum.

Naphtha, or fluid petroleum, is produced during the distillation of bituminous matters. Large quantities are obtained in the distillation of coal, and in the manufacture of pyroligneous acid.

Naphtha does not combine with water, but imparts a peculiar smell and taste to it. With strong alcohol, ether, and essential oils, it unites in all proportions. It dissolves sulphur, phosphorus, iodine, camphor, most of the resins, wax, and fats, as also caoutchouc, which it converts into a varnish. Ordinary pitch gives, upon distillation, a light liquid like natural naphtha; but, according to MANSFIELD, they are not identical, for the former, as has been shown by this chemist, HOFMANN, and others, is a compound of many volatile liquid hydrocarbons, which are not found in the latter.

Naphtha has been applied to several important uses in the arts. It is of great value for out-door

illumination, for which it is employed very extensively; it is also much used as a solvent for caoutchouc in the preparation of varnishes. When incorporated with soap it is said to deprive that detergent of its causticity, which reacts with great irritation upon delicate skins.

Solid bitumen is of three distinct kinds—namely, the earthy, the elastic, and the compact; the latter is termed asphalt. Earthy bitumens have a brownish-black, dull colour, with an earthy, uneven fracture, and soft enough to take an impression of the nail; they burn with a clear, brisk flame, emitting a powerful odour, and depositing much soot. Elastic bitumen is of various shades of brown; it is soft, flexible, and elastic; it has an odour strongly bituminous, and is of about the density of water; it burns with a clear flame and much smoke; by a gentle heat it may be converted into a substance resembling petroleum or asphalt, according to its previous consistence. Like caoutchouc it takes up the tracings of pencils, and on this account it is called *mineral caoutchouc*.

ASPHALT.—*Compact Bitumen*, *Mineral Pitch*; *Bitumen Judaicum*, Latin; *Erdpech*, *Bergpech*, German; *Goudron Minéral*, French.—Compact bitumen or asphalt is, as instanced above, extensively disseminated. It is of various degrees of quality, according to the quantity of impurities which accompanies it; but by simple operations the several species may be reduced to a state of equal purity, and the asphalt then possesses nearly the same properties from whatever bed or country it is obtained. Asphalt has a density less than water; but in consequence of the ingredients mixed with it, the gravity, when of the purest kind, is not less than 1·0 to 1·16, and frequently it is as high as 1·6. It has a black or brownish colour, a resinous appearance, a conchoidal fracture, and when rubbed a slightly bituminous odour; it is opaque, brittle, and does not soil the fingers. The method generally adopted for purifying the natural asphalts is by boiling or macerating them with hot water, according to the freedom with which they part with the earthy and siliceous matters in suspension. During the action of the water the sand and other ingredients fall to the bottom of the vessel, and the bitumen rises to the surface, or forms clots on the sides of the boiler, whence it is skimmed off and thrown into a large cooler, where more water separates. To purify the bitumen thus obtained more completely, it is thrown into a conical-shaped caldron, and boiled for some time, during which the water and volatile matters accompanying it fly off, and the sand and other mineral substances fall to the bottom of the boiler, leaving the asphalt in the form of a thick fatty pitch, in which state it is sent to market, or applied to the various uses which it is made to serve. Such is the method followed at the Seyssel and Bechelbronn deposits, and in various other places. In the former of these, which is the most celebrated, there are three beds of bituminous matter; the first is sandy; the second calcareous and very fusible; and the third calcareous, and not easily fused.

The Bechelbronn variety appears in the form of a bituminous sandy deposit, between two layers of clay; the working of the veins in both places is carried on by shafts and galleries.

The bituminous schist lying near a stratum of lignite at Lobsann, when acted upon by boiling water, manifests a difference in its nature from those mentioned, as the bitumen from it does not enter into fusion like the others, but rises as scum to the surface, from which it is removed by skimmers in the usual way, and remelted at a higher temperature for the purpose of driving off water and separating the sand, which is done by decanting the bitumen after the impurities have subsided. The clayey and siliceous residue is used to manufacture gas, and the bitumen employed for common asphalting.

At ordinary temperatures the asphalts of Seyssel and Lobsann are very tenacious, and in cold weather they become completely solid; the Payta deposits, those of Magdalena and Trinity island, yield similar bitumens. The Bechelbronn bitumen is viscous, and of a brown colour. It is applied for many useful purposes, particularly as a substitute for grease to lessen the friction of machinery, and also for greasing the wheels of carriages. From being applicable to these and similar uses, it has been called mineral fat, Stein oil, Strasbourg grease, &c.

Little was known of these bodies previous to the researches of BOUSSINGAULT, EBELMEN, BERTIER, and others; but by the labours of these chemists, especially the first two, their nature and composition are now pretty well understood. BOUSSINGAULT found that on submitting the asphalts or bitumens of Seyssel and Bechelbronn to distillation, they yielded more or less of a pale yellow oily liquid, which he named *petrolene*, on account of its being always an essential ingredient of petroleum. When those bitumens are heated to 212° nothing passed over, showing that they contain no naphtha; but on raising the heat to about 450° Fahr. the oil was disengaged. According to this chemist, this oil when pure is of a light yellow colour, possesses a bituminous odour, and has but little taste; it boils at 536° Fahr. (280° C.), giving a vapour of the density 9·415.

The specific gravity of petrolene at 69°·8 Fahr. (21° C.) is 0·891. It burns with a very sooty flame, dissolves very sparingly in alcohol, but ether takes it up in greater abundance. Its composition may be represented by $C_{20}H_{32}$. It contains, according to BOUSSINGAULT, 87·2 per cent. of carbon, 12·1 per cent. hydrogen.

By treating the petroleum—viscid bitumen—of Bechelbronn with alcohol it assumes great consistency, and the spirit becomes charged with the petrolene; but it cannot be wholly removed by this solvent even when submitted to distillation, for as the alcohol loses its fluidity by uniting with portions of the matter, it also loses its solvent action in proportion.

The best way to proceed is to keep the mixture at a temperature of about 482° Fahr. (250° C.) by means of an oil-bath, till it no longer loses weight. By this means the petrolene is entirely separated, and a solid body remains, which is black, very

brilliant, has a greater density than water, and breaks with a conchoidal fracture; it burns like resins in general, leaving a very abundant coke. As this body possesses all the characters of asphalt, and forms the essential part of that bitumen, BOUSSINGAULT named it *asphaltene*. It gave, upon analysis, —carbon, 74·2; hydrogen, 9·9—from which BOUSSINGAULT derived the formula, $C_{80}H_{32}O_3$. GERHARD prefers the formula $C_{20}H_{30}O_3$, and considers that asphaltene is produced by the oxidation of petrolene.

The following table shows the composition of a few of the bitumens:—

	Carbon. Per Cent.	Hydrogen. Per Cent.	Oxygen. Per Cent.	Nitrogen. Per Cent.
Viscous bitumen of Bechelbronn,	88·0	12·0	—	—
Virgin bitumen of "	88·0	11·0	—	1·0
Liquid bitumen from Hatten, Lower Rhine,	88·0	11·6	—	0·4
Solid bitumen of Coxitambo, near Cuença, in Peru,	88·7	9·7	1·6	

Annexed is a table of the analysis of several asphalts:—

Centesimally represented.

	Bitumen of Bastennes.	Bitumen of Pont do Chateau, Auvergne. Crude.	Bitumen of Pont do Chateau, Auvergne. Pure.	Bitumen of Abruzzi. Crude.	Bitumen of Abruzzi. Pure.	Bitumen of Monastier, Haute Loire.
Oily matters, (Bitumen)	20·0	—	—	—	—	7·0
Carbon, (Bitumen)	3·7	76·13	77·5	77·64	81·8	3·5
Hydrogen,	—	9·41	9·6	7.86	8·4	—
Nitrogen,	—	12 66	12·4	1·02	1·0	—
Oxygen,	—		0·5	8·35	8·8	—
Water,	—	—	—	—	—	—
Gas and vapor,	—	—	—	—	—	4·5
Quartz sand and mica,	76·3	—	—	—	—	4·0
Clay,		—	—	—	—	60·0
Ashes,	—	—	—	—	—	Ferrug. 21·0
	—	1·80	—	5·13	—	—
	100·0	100·00	100·0	100·00	100·0	100·0

Bitumen of Bastennes much resembles the sandstone variety of Seyssel, but it is much richer; it is compact and homogeneous in appearance, and of a dull brown colour. Although it is solid at ordinary temperatures, yet it softens in the hand, and therefore cannot be pulverized. Boiling water separates bituminous matter only in very small portions, but ether and spirit of turpentine freely remove the whole of the bitumen. Alcohol has little effect upon it in the cold, and dissolves only very small quantities at a boiling temperature. This bitumen is used in the proportion of 8 or 10 per cent. with the Seyssel asphalt in making mastic.

The asphalt of the Pont de Chateau is solid, but likewise softens in the hand, and melts completely at a moderately high heat. It has a conchoidal fracture and a fine black colour; its density is 1·068 at 53°·6 Fahr. (12° C.). It dissolves almost completely in turpentine, but only partially when treated with ether. If it be thrown upon the fire, it burns with a crackling noise, and scintillates, on account of the evolution of water; when, however, it is heated in a glass tube gradually, it intumesces, and parts with its water without any decrepitation.

Asphalt of Abruzzi is solid, very brittle, has a conchoidal fracture, and shines like jet. Ether scarcely attacks it, but it is largely dissolved in essence of turpentine. At 55·4 Fahr. (13° C.) it has a density of 1·175; it begins to soften at 212° Fahr. (100° C.), and fuses completely at 284° Fahr. (128°·8 C.) without losing water.

Three kinds of bituminous mineral have been discovered at Monastier, in Haute Loire, which considerably differ from those above mentioned, inasmuch as they are not in the least acted upon by boiling water; and neither agglutinate nor soften when ignited, but burn with a vivid flame, leaving a dark-brown ash.

Ether and oil of turpentine readily attack these bitumens, yielding deep red-brown liquors, but do not completely dissolve them; alcohol abstracts rather more bitumen from them than ether and oil of turpentine. When distilled, they evolve oils and much water.

Bitumen of Cuba is largely imported into Europe, and passes by the name of asphalt of Mexico, or Chapopota. It comes in reality from the environs of Havannah, in the island of Cuba, where it exists in abundance. DUMAS, speaking of this bitumen, says it is solid, very brittle, conchoidal with a large fracture, and of a very fine black; but its powder takes a brown tint; it exhales a very strong though not unpleasant odour. Grains of quartz sand may be distinguished in it here and there, and also particles of wood and straw. Its density differs little from that of water; some pieces swim in that liquid, and others sink to the bottom. It softens at a moderately elevated temperature, and melts completely in boiling water into a thick liquor, which rises and floats upon the surface in the form of a scum or pellicle. Acids and alkalies leave it intact. Alcohol dissolves a small portion of it, and the solution afterwards becomes milky upon the addition of water. Ether and oil of turpentine abstract half its weight, leaving a granular black substance, fusible at a temperature above 212° Fahr. (100° C.). The ethereal extracts have a deep red hue, and when they are evaporated, the bituminous matter remains soft and transparent, and of the same colour. When calcined in close vessels, it swells up and leaves about 0·10 per cent. of a brilliant and extremely light coke. The oils which separate from it are brown and viscous.

Considerable quantities of bitumen are imported from the Dead Sea, in Judea, on the shores of which it is thrown up and collected; hence its commercial

name is Jewish bitumen. This variety has a density of 1·16; it resembles ordinary pitch in colour and fracture. Boiling water melts it; and when distilled it yields a peculiar bituminous oil, some water, and traces of ammonia. It leaves about one-third of its weight of charcoal, which, upon being burned, affords an ash composed of silica, alumina, oxide of iron, with traces of lime and manganese.

The Tar Lake of Trinidad is about 3 miles in circumference, and of an unknown depth, and forms the largest bituminous deposit in the world. It is situated in the highest part of the island. The odour from it is perceptible for many miles. To a distant spectator it appears like a sheet of water undisturbed by the least ripple; on a nearer approach it looks as if it were glass. It has been found that this bitumen, which is quite solid at the surface, is soft when cut into, and is interspersed with cells, which contain petroleum. In hot weather the surface of the lake softens to the depth of an inch, and therefore cannot be walked upon at those seasons. Large fissures frequently occur, and from this circumstance the pitch is supposed to float upon a body of water. In the neighbourhood of the lake liquid bitumen is found in holes and fissures in the ground, to the depth of about 2 inches; the soil also presents indications of volcanic action. The bitumen from this lake does not easily burn, but a gentle heat renders it ductile; it is not much used for asphalting purposes. When mixed with grease it answers well for coating the bottoms of ships, to protect them from the small worms known as *teredines*.

Some years ago asphalt produced an industrial fever almost without a parallel in manufacturing annals; at that period the product was extolled beyond measure, and uses were assigned for it in every branch of the arts and manufactures, even in cases where common sense alone might have been sufficient to demonstrate its inefficiency. A reaction, unfortunately too complete, soon took place, and it fell into undue discredit; but now it is slowly recovering in public estimation, and it is certain that its valuable qualities of plasticity, fusibility, adhesiveness, impenetrability to water, &c., unchangeableness under ordinary conditions of the atmosphere, turned to account with discrimination and judgment, will render lasting services to many departments of industry.

The chief use of asphalt, at present, is in making floors and laying down pavements and roads.

A recent application consists in preparing conduits of large dimensions, by means of thin tubes of sheet iron, if covered externally with a coating of bituminous mastic, of from 1 to 1½ inch in thickness. These economical conduits were devised by M. CHAMEROI, and employed by him in Paris. Pipes of bituminized glass were proposed by M. HUTTER, and made in the glass-works of Rive-de-Gier, but did not come much into use.

It appears, however, that bituminous mastic or asphalt may be applied to a variety of purposes, analogous to those which have just been indicated. The tar may serve directly, and without being transformed into asphalt, for several rather important uses. It has already been employed for impregnating paving-flags of sandstone, bricks, and other building materials; it communicates to these different objects the qualities which belong to itself. It is sufficient for this use of it to heat the tar to 302° Fahr. (150° C.), and to plunge in it the sandstone or other materials of loose texture for two or three hours. The muriatic acid towers of alkali works have been constructed of such materials, and answered exceedingly well.

Earl DUNDONALD first proposed to make pipes, pillars, pedestals, bases, &c., from Trinidad bitumen. Combined with cloth, he proposed to make it useful as a covering for ships' bottoms, between the vessel and the metallic sheathing, and as a lining for coffins. Another, and the most useful of his applications of this important substance, was the coating of electric telegraph wires.

Bricks of very bad quality become excellent for various purposes after being saturated with mineral tar (see page 368).

It is a very remarkable fact in the history of the useful arts that asphalt, which was so generally employed as a solid and durable cement in the earliest constructions upon record, as in the walls of Babylon, for example, should, for so many thousand years, have well nigh fallen into disuse among civilized nations.

France has lately been most diligent in rendering this article subservient to her comfort, so much so that her capital and large cities may be said to have become as museums of asphaltic appliances. The mines of asphalt in Alsace offer, on account of their quality, considerable advantages and inducements for her advancement in this department.

For asphalting roads, streets, &c., the two great requisites are, first, a concrete or bituminous stone, where the mineral constituents are so blended and enveloped in the bitumen as to be unaffected by contact with air or moisture for any length of time, and also to be able to resist sudden changes of temperature without being injured thereby; this forms the basis of the asphalting. Secondly, a mastic or bituminous cement, which may be occasionally used with the former to give it more fluidity, and which is in like manner proof against air, moisture, and sudden changes of temperature.

The best concrete is thought to be that from Neufchatel; it is massive, of irregular fracture, of a liver-brown colour, and is interspersed with a few minute spangles of calcareous spar; it is easily scratched by the nail, but is still very irrefrangible. When exposed to heat it evolves a fragrant ambrosial smell, a property which distinguishes it from factitious bitumen. Its density is 2·114, or nearly equal to that of bricks. When treated with oil of turpentine it affords 80 per cent. of a white pulverulent carbonate of lime and 20 per cent. of bitumen.

The qualification giving its superiority to native bituminous concrete and mastic over artificial asphalt, is the intimate combination of the mineral and organic constituents that enter into their composi-

tion. No artificial preparation of this kind, whatever may be the pains bestowed upon it, can be so homogeneously, or its constituents so closely combined, as the natural compounds, for no means are employed to produce these necessary qualifications further than a comparatively feeble heat, whereas the natural substance must have been formed under the influence of a high temperature and an enormous pressure; hence the intimate union of the two principal ingredients is exceedingly perfect.

The concrete from Neufchatel may be rendered suitable for asphalting by mixing with it a definite amount of the mineral tar of Seyssel or Bechelbronn, the mixture being rendered homogeneous by fusing it in a sheet-iron caldron. Common tar is sometimes used for the purpose, but petroleum is much to be preferred.

At Lobsann, the asphalt is purified, as before stated, by the action of boiling water, and is subsequently fused by itself, to disengage water and volatile impurities. After the process of purification, it is melted and incorporated with bituminous limestone, pulverized and dried. When the mixture is sufficiently consistent it is brought to a table on which sheets of paper are laid, and upon these a square frame, intended to receive the plates of mastic, is placed; the mastic is poured out and spread by means of a heated iron roller. There is a division in the frame, by which two plates are obtained, making together a little more than a square yard. The plates are sprinkled with bituminous sand, and may then be piled up in stock or packed in bales. They are used with the sheet of paper beneath them. When laying these plates they are united by a hot iron, and can be removed and soldered afresh in a similar manner, if required.

The beautiful mosaic asphalt of the Place de la Concorde in Paris was laid as follows:—The ground was made uniformly smooth, either in a horizontal plane or with a gentle slope to carry off the water; the curb stones were then laid round the margin by the mason, about 4 inches above the level. This hollow space was filled to the depth of 3 inches with concrete, containing about a sixth part of hydraulic lime, well pressed upon its bed. The surface was next smoothed with a thin coat of mortar. When the whole mass had become perfectly dry the mosaic pattern was set out upon the surface, the moulds being formed of flat iron bars, rings, &c., about half an inch thick, into which the fluid mastic was poured by ladles from a cauldron, and spread evenly over.

The mastic was made by roasting the asphalt in an oven about 10 feet long and 3 broad, to bring it to a friable state; the bottom of the oven was sheet lead, and was heated by a brisk fire beneath it. A volatile matter (petrolene), to the amount of the one-fortieth of the weight of the substance, was driven off, and the residue, after roasting, became so friable as to be easily reduced to powder and passed through a sieve, having meshes about one-fourth of a square inch. The bitumen destined to render the asphalt fusible and plastic, was melted in small quantities at a time in an iron caldron, and then the latter in powder was gradually stirred in, to the amount of twelve or thirteen times the weight of the former. When the mixture became fluid nearly 2 gallons of very small gravel, previously heated apart, was stirred into it; and as soon as the whole began to simmer and acquire a thick syrupy consistence, it was fit for use. It was then taken in buckets and poured into the moulds.

Asphalt has been laid down in a great number of the public places and streets of Paris. The pavements are said to give great satisfaction, from their continued cleanliness and resistance to the air and general traffic. In London, its application to paving purposes has not been so successful as anticipated, owing to its slipperiness in damp weather.

In making asphalt pavements it is essential to boil the bitumen thoroughly, in order to expel the water and volatile oils, with which it is always impregnated, or else it will not, when laid down, resist so effectively as it might the extremes of heat and cold, neither will it remain unaffected by wear and tear. In preparing the natural asphalt, it is better to pulverize the rock by means of heavy iron rollers, than to disintegrate it by heat, as described in the foregoing paragraph; in both processes for sifting the dust, however, a sieve is employed of ten meshes to the inch.

The object of the trituration is to convert the asphalt into mastic. For this purpose a certain quantity of vegetable bitumen is added, proportional to the quantity of asphaltic rock then transformed into asphalt powder. Thus, for those operations in which the cement requires to be endued with considerable elasticity, the proportion of bitumen ought to be greater; the contrary will be the case for firm and hard substances; and this proportion will still be different when the mastic is employed as a natural mortar.

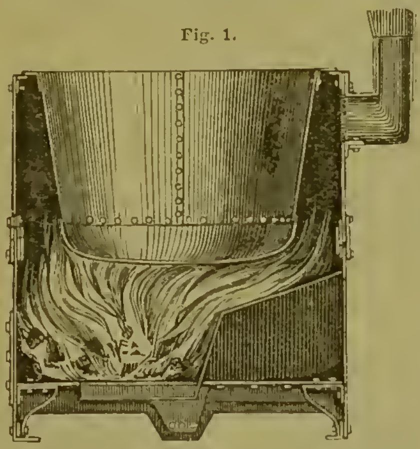
In certain cases asphalt is used in the state of powder, and not in the form of mortar; but this mode of applying it presents disadvantages which it is necessary to avoid, in order to obtain the conditions required for its good applications.

The most advantageous use of natural or artificial mastic consists in applying it to the purpose of obviating the bad effects arising from moisture. It is excellent for protecting houses against damp; in this case it ought to be applied in thin layers to cover the whole surface of the ground. It may be used as a roofing; for cementing tanks, fountains, and cisterns, which it protects from any infiltration; as a substitute for pavement, macadam, and flags, in roads, courtyards, footwalks, &c. Terraces are rendered impermeable to moisture by means of a layer of asphalt, and in such cases it proves a highly economical substitute for sheet lead.

In Claridge's process of asphalting the blocks of mastic are fused in a portable boiler, similar to Fig. 1, and a quantity of mineral tar added, in the proportion of 1 lb. to every cwt. of the mastic. The tar is fused in the boiler, the mastic then introduced to the amount of 56 lbs., and the whole repeatedly stirred to prevent depositions. As soon

as the contents of the boiler have been properly melted, the cauldron is covered over for a quarter of an hour, after which the remaining quantity of the mastic is added, and its fusion proceeded with as above, the process being repeated until the boiler is full, allowing an interval of from ten to fifteen minutes between each operation. When the mastic is sufficiently fluid it will drop freely from the stirrer, and jets of light smoke are observed to issue from it. If stiff mastic be required, the proportion of tar is

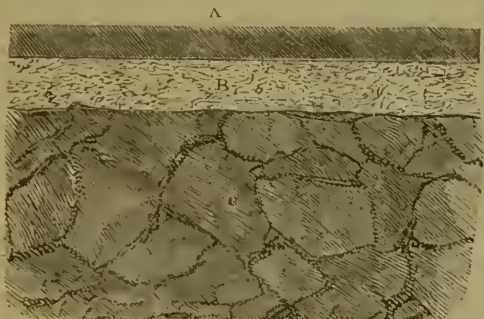
Fig. 1.



lessened, and a quantity of coarse grit or river sand, to the amount of 20 or 30 lbs. to the cwt., added.

In laying the asphalt, the greatest attention and care must be devoted to the preparation of a solid and dry foundation. This is usually accomplished by removing or ramming the loose earth, and placing upon the bed a layer of coarse sand mixed with powdered limestone, in the proportion of seven parts of the former to one of the latter, and the whole pressed or beaten solid; upon this a second layer of finer materials is laid, compacted, and levelled; the

Fig. 2.



bed thus prepared is allowed to dry before coating it with the mastic.

Fig. 2 shows the manner in which ordinary asphalting is laid down. In this figure, C is the bed of coarse concrete, B the second and finer layer of the same material, and A the superior layer of asphalt.

Unless the base, or concrete, be perfectly dry when the mastic is poured on, the work will not be successful, for the water will be converted into steam, which, issuing through the fluid mastic, will cause the formation of holes in the latter, or blister it, and ultimately the surface will crack. For this reason, winter is the worst season for laying down asphalt, except in places under cover. To counteract in some measure the evil arising from the formation of steam, it is found advantageous to sift fine cinder dust over the bed of concrete previous to the laying on of the liquid mastic. The depth of the layer of mastic is regulated by slips of wood, so arranged as to divide the surface into compartments of convenient size, and when laying the asphalt these compartments are filled up alternately; in this way there is no fear of one part being injured or defaced by the workman, as the alternate layers will be quite stiff when the intermediate spaces are being done. A curved wooden spatula, to which a straight rule of the breadth of the compartment of asphalt, and the ends of which move upon the slips of wood embedded in the concrete, is affixed, is rolled back and forth immediately after laying on the mastic, to bring it to the proper level.

When the surface is to be retained smooth, a mixture of equal parts of fine sand and slate dust, or 2 parts of sand and 1 of hydrated gypsum, or powdered chalk, is sifted over it before it is completely set, and rubbed in with a flat heavy wooden tool.

For roads and pavements, fine river gravel, or coarse grit, is scattered thinly over the surface of the mastic before it is hard, and beaten into it.

When asphalting suspension bridges, a sheet of canvas is generally spread over the concrete.

In asphalting damp places, such as cellars and foundations, a brick invert is always laid in asphalt beneath the concrete. The manner of doing this is by placing the bricks in rows at the proper depth and slope, and pouring a coating of asphalt about a quarter of an inch thick upon them. Before the mastic solidifies, the bricks are separated a little by passing a knife between them, thus affording the mastic an opening by which to seal up more thoroughly the connection. The concrete is afterwards laid upon this bed, and the layer of mastic upon this in the usual way. The thickness of the layer of mastic varies according to the attrition to which it is to be subjected; but the usual depth is from a quarter to one and a quarter inch.

In France, the following are the operations pursued in laying it. The general preliminary is to dress the ground, and beat it down well so as to render solid; it is then covered with a layer of pitch, 4 inches thick, and this is again covered with a thin layer of mortar mined with fine sand.

The pitch is left to harden for some days, to avoid the bubbles and swellings which would otherwise appear on its surface, after which the asphalt is spread upon it to the thickness of half an inch or more.

The ingredients are applied in the following proportion per square mètre—$10\frac{3}{4}$ square feet:—

FOR HALF AN INCH.

Mastic,............................	44	pounds.
Gravel,............................	$26\frac{1}{2}$	do.

FOR THREE-FIFTHS OF AN INCH.

Mastic,............................	53	pounds.
Gravel,............................	30·8	do.

It has been acknowledged that the flooring of stables is of great importance to the health of the horses; this has caused a particular flagging to be sought after, which consists in spreading an asphaltic pitch of four-fifths of an inch in thickness on the ground, previously well dressed and beaten; then, by means of a grooved iron roller which is drawn along the band or belt of bitumen, a paving in relief is obtained, which drains off the water well, and resembles that laid in the ordinary manner.

It is in works connected with lines of railway that the use of bitumen is most fully appreciated. Thus, the copings of arches, of tunnels, and bridges, when covered with a coating of pure bituminous mastic, unmixed with gravel, completely prevent the infiltration of rain-water. As the earth-covering above might contain stones, which would penetrate into the bed of cement, a coating of clay is generally spread over the asphalt to the depth of 1 or 2 inches.

For constructing terraces, the following arrangements must be made:—

If the ground of the terrace is of masonry, the surface must be well put together, and the joinings carefully closed; it is then covered with a layer of asphalt half an inch thick, mixed with half its weight of fine gravel.

When the building on which the terrace is required is of timber, the flooring must be formed with planks at least four-fifths of an inch in thickness, arranged very close to one another, and firmly nailed to the supporting beams or joists.

This flooring is spread with a layer of pitch an inch or two in thickness, mixed with a little chopped hay or moss, to increase the elasticity of the ground.

The pitch having time to be well solidified, is then covered with the asphalt in the same manner, and under the same conditions, as in the case of terraces constructed on masonry.

The surface of the layer of asphalt ought to be grained over with fine sand, firmly compressed and beaten down, to intercept as much as possible the rays of the sun.

The application of two layers would afford still further security.

QUANTITY OF INGREDIENTS EMPLOYED PER $10\frac{3}{4}$ SQUARE FEET.

Asphalt,..............................	55 pounds.
Gravel,..............................	28·7 do.

By having the flooring of granaries asphalted, the different kinds of grain are secured for a long series of years from the damage to which they are liable when kept in the ordinary stores.

In the lining of cisterns and reservoirs, the danger to be chiefly apprehended is the infiltration and absorption of the waters which they contain. The mode of applying asphalt to obviate these disadvantages is exactly the same as when it is applied to the construction of store-pits.

Asphalt is also employed as *natural cement* in the construction of tunnels, to guard against the infiltration of water, and thereby avoid great inconveniences.

The principal points to be attended to in the construction of tunnels, are the same as when this kind of work is performed in the ordinary manner; only the stones must be perfectly dry, and brushed clean, if required, to facilitate the adherence of the asphalt, which ought to be from one-sixth to one-fourth of an inch in thickness between two consecutive stones.

BABONEAU invented for the Val-de-Travers Asphalt Company a portable boiler, or melting vessel, provided with an agitator, by means of which the fusion and trituration of the asphalt with the bitumen, and then the mixture of the gravel with the mastic thus formed, can be performed at the place where the asphalting is to be done.

This improvement has done much to promote the application of asphalt for useful purposes; it is no longer necessary, in fact, to prepare in the manufactory the blocks of asphalt and bitumen, an operation which required a special apparatus. The substances, as they were found in nature, are now transported in sacks to the place where they are to be used; and the melting, trituration, and mixing, are performed on the spot at the moment when the substance is to be laid down. Moreover, the melting vessel is so ingeniously constructed, that it collects the gases, and absorbs the greater part of the disagreeable odour which melted asphalt evolves.

ARTIFICIAL ASPHALT.—This is prepared from the tar produced at gas-works. To prepare asphalt it is requisite to transform this liquid tar into a fatty pitch, and for this purpose the essential oils, which hold the solid matter of the tar in solution, must be completely distilled off; and the boiling must be continued till a sample, when cooled, becomes nearly solid.

The evaporation of the tar may be very well performed in the open air; but if it be desired to avoid the odour exhaled by the essential oils, and to collect the latter, which have a certain commercial value, it is necessary to conduct the operation in close vessels.

An apparatus, which gives very good results, consists of a still-retort of sheet iron, with a bottom made convex in the interior, placed immediately over a fire; the products of the combustion, after striking the bottom of the retort, circulate round it, then proceed under a second boiler to heat the tar contained in it, and from which the retort is replenished when requisite. This vessel, when three quarters full, contains nearly 24 cwts. of tar; it should be perfectly embedded in masonry; the capital itself, by which the volatile products escape, ought to be covered with materials that are bad conductors of heat, such as ashes, &c. Without these precautions the essential oils would condense and fall back indefinitely into the evaporating boiler. To collect the oils, they are made to pass into a tube cooled by a current of water proceeding in an opposite direction to that pursued by the vapours: they are then received in a close vessel. A tube, branching from the vessel, conducts the uncondensed products outside the building in which the distillation is performed. This precaution is necessary to avoid the risk of conflagration; for these condensable oils have always a certain tension, and consequently

yield vapours tending to diffuse themselves in the atmosphere.

When the tar is brought to that state in which it assumes a sufficient consistence on cooling, it is withdrawn through a large pipe, and received into a third hemispherical boiler of cast-iron.

To prepare the bituminous mastic directly from this fatty pitch, the latter is kept in a state of fusion by a supplementary fire placed under the cast-iron boiler, and chalk in sufficient quantity is then added. The chalk ought to be previously ground to a coarse powder, dried on plates of cast metal, and then passed through a sieve of iron wire. By adding heated chalk to the pitch, the mixture is accomplished better and more rapidly. The mastic is more solid in proportion as a greater quantity of chalk is added; but, on the other, it becomes less binding and more brittle. To mould the bitumiuous mastic, and thus impart to it a convenieut form, a long table is spread over with cast-iron plates. A frame surrounds the table, which is subdivided into eight or ten compartments, by means of rules of about 6 inches in height, introduced vertically into grooves formed at equal intervals in the long sides of the frame. The eight or ten moulds obtained by this arrangement are coated internally with a paste, composed of sixty parts of water and forty of chalk, and which has the effect of preventing the adherence of the mastic to the sides of the mould.

Two barrels of tar, of 4½ cwts. each, or 9 cwts., lose by distillation one-fourth, which is composed of 1 cwt. 3 qrs. 15 lbs. of volatile essential oils, and 1 qr. 13 lbs. of water; there remain, therefore, about 6 cwts. 3 qrs. of fatty pitch. The essential oils procured by the distillation of gas tar have of late years received much attention from manufacturers, on account of their utility in the preparation of varnishes, and for lubricating machinery, as illuminating media; and for the preparation of a superior kind of lampblack. (See COAL-TAR DISTILLATION.) Again, by blending it with coal gas, it renders its illuminating power greater; for this purpose it is sufficient to pass the gas over the surface of a shallow vessel covered with these oils. Many patents have been taken out for apparatus to effect this mixture.

Asphalt, as generally used in this country, was formerly made from ordinary pitch, boiled down with a species of dark-brown bituminous limestone from the Jura mountains, previously ground and dried for the purpose. The limestone is, however, only employed in the manufacture of the better kinds, for chalk is often substituted, and some allege with results equally good. The proportions taken are regulated by the use to which the mastic is subsequently to be applied; and having mixed them they are boiled down to a thick liquid, after which the semifluid mastic is run into square or circular moulds to cool, when it forms blocks of about 140 lbs. each.

Sometimes ground or fine sand enters into the asphalt in equal proportion with the chalk or limestone; but, in some instances, only half as much sand as of chalk is used. It is necessary during the fusion to keep the contents of the caldron well stirred, as well to prevent the tar adhering to its bottom, by which it would get burned, as also to bring the ingredients into intimate combination and to give the mass a homogeneous composition. As soon as the whole is thoroughly mixed, the proper consistency acquired, and aqueous and oily vapours are found to be disengaged only in very minute quantities, the asphalt is run off into the moulds as before stated; and in this form it is conveyed to the place where it is being laid down.

Dr. G. HAND SMITH has recently patented a process for making artificial asphalt, waterproof concrete, &c., which promises to become of great value for sea walls, docks and harbour works, &c. His invention consists in filling up the interstices of any porous substance, such as brick, burned or unburned clay, soft stones, plaster of Paris, &c., with pitch or tar which has been boiled to such a consistence that the pores or cells of the material used are completely filled with solid matter when cold.

Other hydrocarbons, resins, or gums, may be used instead of pitch and tar, but it is essential that the saturating substances, though naturally fluid or semifluid, can be so changed by boiling that they lose their fluidity when cold; or they must be, though hard under all ordinary temperatures of the atmosphere, capable of reduction by heat or otherwise to a fluid conditiou, so that they will penetrate the porous materials.

If tar is used, it is first boiled long enough to give it, when cold, about the consistency of pitch, although its fluidity is retained while it is kept hot. In the heated tar the brick, sandstone, or other similar porous material, is immersed until the pores are completely filled with the liquid. When thoroughly saturated the material is removed from the tar and allowed to cool.

When pitch is used, it is simply melted, and then the saturatiou of porous material effected as with coal tar.

Or a mixture of pitch aud coal tar may be used, provided it has been previously so long heated that it will harden on cooling. Merely soaking iu hot coal tar will uot answer the purpose.

By au adaptatiou of this process, Dr. G. HAND SMITH produces a waterproof coucrete of great beauty and durability, which can be cut or turned in a lathe, and is susceptible of a brilliant polish.

Clay, plaster of Paris, or chalk, moulded or cast into any desired form, is saturated with gas tar, or pitch, or a mixture of the two, by immersion in a boiling bath, until ou removal no adhering film is perceived. Great care must be takeu not to touch or handle the articles on removal from the bath, or they will probably fall to pieces. It is not always necessary for the fluid to penetrate completely through the object treated. Sometimes saturation to a slight depth only is desirable.

Without beiug allowed to become perceptibly cool, the saturated material is then heated in an oven, to drive off the volatile portions of carbon or other volatile matter, so that only the solid and non-volatile portions of the carbon shall be retained in the pores.

The degree of heat to which the articles are subjected of course varies somewhat with the material used and the precise result sought to be obtained. The heating and cooling should be gradual. The proper heat is usually indicated by the loss of odour and the toughening of the material treated.

If the bath consists entirely or nearly so of pitch, it may be heated to a very high temperature, and in some instances no after-heating of the porous material in the oven will be necessary, as the heat imparted in the bath is so great that in cooling in the air after immersion sufficient volatile matter will be driven off. If the objects are to be heated to redness, they must be inclosed in retorts to prevent the combustion of the carbon.

Pulverized clay, plaster of Paris, chalk, and the like, may be first mixed with coal tar, pitch, &c., moulded or pressed into form, and then subjected to heat, as above described.

The following is the mode of making artificial asphalt or "carbonite" (as its inventors term it), for building sea walls, which has been devised and patented by G. Hand Smith and H. C. Paterson. The new transfer docks in Glasgow are to be built of this material. The outer walls are of moulded blocks laid in courses, the space between being filled in with the carbonite while hot.

Two mixtures are made. The first mixture or compound is thus composed:—

Ordinary green or boiled coal tar, about........	15 to	25	parts by weight.
Small broken stones, sand, or shingle, about......	985 to	975	parts by weight.
	1000	1000	

It will be seen that the quantity of coal tar is very small. It should be heated before it is used, so that it may flow readily. If instead of green or boiled coal tar, the ordinary tar from which the heavy oils have been distilled should be used, a larger proportion will be required.

The above ingredients are mixed in a strong pug mill, at a heat which is gradually increased until the pebbles become adhesive to the touch. When the ingredients have been brought into this condition, a second mixture is introduced into the mixing apparatus. This mixture is thus prepared:—Clay and pitch are taken separately, in about the following proportions:—

Pitch about............	250 to	335	parts by weight.
Clay, dried or anhydrous, about................	750 to	665	parts by weight.
	1000	1000	

The solid pitch is ground with the dry clay, and the powder thus produced is thrown into the pug mill, while its contents are adhesive to the touch. The proportion of the pitch mixture should be about 12 per cent., viz.:—

Of the first compound, about	880 parts by weight.
Of the second compound, about	120 parts by weight.
	1000

The whole mixture is then shut in by a close fitting lid (the vessel must be provided with a safety valve, and may be heated by a steam jacket or otherwise), and the heat raised to about 250° Fahr., or to a higher temperature in proportion to the hardness which it is desired to impart to the manufactured material; it should not in any case be carried higher than about 350° Fahr., as at higher temperatures the plasticity of the mixture is destroyed. The mixed ingredients must be well agitated, so that the vapours generated may diffuse themselves uniformly throughout the mass. So soon as a sample is found on moderate compression to become hard and to be tough when cool, the "carbonite" is removed while hot to moulds, where it is pressed and shaped into blocks of the required size, by machinery if requisite, though for ordinary purposes a hand rammer suffices.

A prominent feature of these carbonite blocks is that for sea walls or piers they can be cemented together with a suitable asphaltic cement beneath the surface of the water, and whilst exposed to the action of moderate waves.

Concrete thus produced is of very great toughness, and when fractured, breaks through the pebbles and stones composing its mass.

BLEACHING.—*Blanchiment*, French; *Bleichen*, German.—Under this designation is understood in general the elimination of colour from various substances by means of some chemical agent. In a special sense bleaching means the purification of certain organic fibres, and of textile fabrics made of them, from coloured and other impurities, which are either naturally associated with them, or are added for some purpose or other in the course of the manufacture of such fabrics. It is in this sense alone that bleaching is understood in this article.

Bleaching is, as already stated, the result of a chemical action of certain substances upon the colour of the fibre. The agent now almost universally employed is chlorine, which is used in the shape of bleaching powder—a compound consisting of chlorine, lime, and oxygen. For the preparation of this substance, its nature, &c., the reader is referred to the article Chlorine.

Bleaching is of very great antiquity, but where it originated is unknown. It may be reasonably supposed that, as soon as human knowledge extended to the manufacturing of clothing, the observation was made that the natural shade of colour in such fabric was destroyed by exposure to the atmosphere and rain, and also by occasional washing; hence the idea of bleaching, by constant exposure to light and moisture for a certain period, may have occurred. But though this proved very efficient, the necessity of having large fields at command, and the great amount of labour and the long period of time which the process required, made it an expensive one. Subsequently sulphurous acid was used and still continues to be employed in many cases.

A cursory notice of the older manner of bleaching, as well as a brief historical sketch of the improvements introduced from time to time, may prove interesting in this place.

The first operation was the steeping, which consisted in immersing the yarn and cloth in a cold alkaline lye, or in hot water; when the latter was used, the steeping lasted for three or four days, but if the bath was alkaline, forty-eight hours sufficed.

The goods after this steeping were washed and boiled for four or five hours, again washed, and exposed on the grass to sun and air for two or three weeks. After this period they were again boiled, or, as it was termed, "bucked," washed, and again exposed on the grass, or "crofted," as before. The alternate operations of bucking, washing, and crofting, were repeated five times, the strength of the alkaline lye being reduced at each successive washing.

Having performed these, the next course was the souring, which, till about the middle of the last century, consisted in keeping the goods steeped during several weeks in sour milk. A writer at this period, Dr. HOPE, suggested the use of dilute sulphuric acid instead of the milk, and by this improvement the time of souring was shortened to about ten or twelve hours. The bleaching was not, however, finished with this operation; the boiling, washing, souring, and crofting, had to be renewed and continued till the cloth appeared perfectly clear, and quite colourless. The period of boiling, &c., varied according to the quality of the goods; linens were seldom finished in less than six months, and cottons required from six weeks to three months.

It is unnecessary to enter into the explanations which older chemists offered concerning the changes effected during the above described course of operation; they have proved more or less inaccurate. Modern writers seem to agree that the principal action which takes place during croft-bleaching is the combination of the oxygen of the air with the colouring matter, resulting in a compound which can be dissolved out by water or alkaline liquors on boiling.

Before proceeding to describe the course of operations as now executed, a little attention must be given to the nature of the materials, and also of the impurities with which they are impregnated. Upon examination it will be found that considerable difference exists between a sample of cotton, hemp, or flax fibre, and one of wool or silk; hence the necessity of applying different methods for their purification becomes apparent.

The materials which enter into the formation of cloths and other fabrics are either of vegetable or animal origin; the first class includes cotton, flax, hemp, and some others; the second, wools and silks.

COTTON (*Coton*, French; *Baumwolle*, German) is the filamentous down enveloping the seeds of several species of *Gossypium*, a plant belonging to the natural order of *Malvaceæ*. The most important species are:—

1. *Goss. herbaceum*, Linn., an annual shrubby plant of about 3 feet high, indigenous in Asia and Egypt, whence it was transplanted to Asia Minor, South Italy, Sicily, Malta, and Spain. Fig. 1 is a drawing of the cotton pod and flower of this plant.

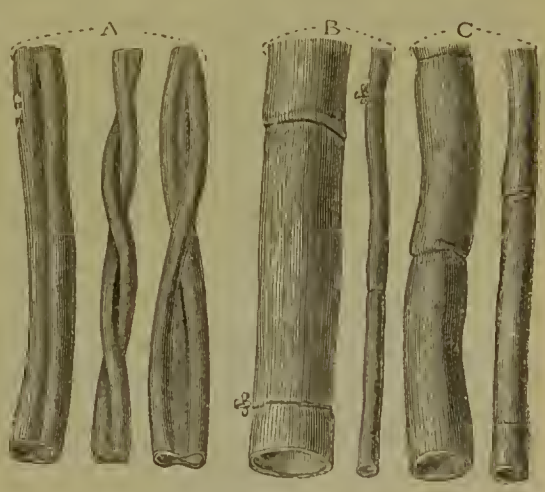
2. *Goss. barbadense* reaches a height of 15 feet, indigenous in the West Indies, but occurring also in Africa and America.

3. *Goss. religiosum*, with a brownish-yellow fibre, at home in China and India.

Fig. 1.

4. *Goss. hirsutum*, the hairy American cotton, of about 6 feet height, largely cultivated in North and South America and the West Indies.

Fig. 2.



5. *Goss. arboreum*, perennial, attaining to a height of 20 feet, to be found in southern Europe and in America.

The fibres of cotton, as shown by the microscope,

are represented by the preceding sketch—Fig. 2—in which the fibres of cotton and flax are contrasted. The fibres, A, are from raw cotton prepared for manufacture; the fibres, B, are those of raw flax before spinning; and the fibres denoted by C, are those of unravelled threads of manufactured flax. All the fibres figured represent each $\frac{1}{200}$ of an inch in length, and are magnified 400 times in diameter. They vary in thickness from $\frac{1}{800}$ to $\frac{1}{3800}$ part of an inch. It will be observed that the cotton fibres, as thus revealed by the microscope, are somewhat flat, two-edged, or triangular, never or extremely seldom cylindrical, but contorted, especially when moistened, and occasionally widened out, in which case they are frequently marked with lines running in a direction oblique to the axis of the fibre. This construction causes the fibres to adhere to each other and causes cotton clothing to give warmth. The fibres of flax, on the other hand, are straight notched tubes with a smooth surface.

The principal constituent of the cotton fibre is cellulose, which forms the substance of the cell; over this lies a delicate skin, the cuticula, which is not composed of cellulose. We learn this from the different behaviour of the two towards certain re-agents. A solution of cupric oxide in ammonia attacks the cellulose portion of the fibre, causing it to swell up into a gelatinous mass, but leaves the cuticula, which is broken into pieces, unchanged; on adding some hydric sulphate, and subsequently a drop of tincture of iodine, the cellulose becomes blue, the torn cuticula yellow.

Cellulose is insoluble in cold and hot water, in dilute acids and lyes, in alcohol, ether, fats, and volatile oils, but dissolves easily in concentrated sulphuric acid, and is likewise destroyed by strong solutions of caustic alkalies. Cream of lime, even hot, does not affect it; but if the lime is allowed to become dry upon the fabric, it soon reduces the fibre to powder—probably in consequence of the formation of carbonic acid and water at the expense of the carbon and the hydrogen of the cellulose.

Cellulose possesses the same empirical composition as starch, gum, and sugar, which is usually expressed by the formula $C_6H_{10}O_5$.

The other not mineral constituents of the cotton fibre are very little known; all that seems to have been ascertained about them is that they are gums, resins, and fatty matters. It is these substances which necessitate the purifying processes to which the fabrics have to be submitted, preliminary to the bleaching action proper.

Besides those natural impurities, there are those which the fabrics take up in the course of their preparation. Such are the weaver's dressing, which is usually starch or size, and the perspiration and filth from the hands of the workmen.

The task of the bleacher would be easy if he had only to deal with the vegetable fibres of the textile fabric, and the colouring matters naturally occurring in it; but the presence of fatty, and still more of the resinous bodies, renders the bleaching operation very complicated. These bodies are not readily attacked by chlorine, and if the operator were to persevere in the application of this agent until fats, resins, &c., had been eliminated, he would by that time also have destroyed the fibres of the fabric. Other means have therefore to be used before the treatment with chlorine can be resorted to.

The bleaching process, as now practised, dates from about the year 1828, when machinery was made to supersede manual labour. D. BENTLEY (of Pendleton) made the first efforts in this direction; and although his early proceedings were not adapted to successfully compete with the rapidly developing improvements of the succeeding years, yet they possess the merit of having given the first impulse to the movement. Among the foremost of those whose labours greatly contributed to the mechanical improvement of the bleaching operation is JOHN GRAHAM of Staleybridge. His arrangements, which greatly assisted to bring the bleaching process to its present simple and almost entirely mechanical form, have been adopted by nearly every bleacher in Great Britain. They are, besides having the advantage of speed in the manipulation, valuable on account of considerably lessening the quantities of the chemical agents required.

The whole operation of bleaching may be divided into the following stages, of which, however, one or the other can, according to circumstances, be omitted:—Stamping and ending; singeing; scouring with water; bucking with lime water and washing; scouring; scouring with caustic alkali and washing; treating with bleaching liquor; scouring; steeping; bucking with caustic soda or its carbonate; souring; washing and squeezing; mangling; starching and dyeing; calendering, folding, and stamping.

Stamping and Ending.—This affords little interest to the chemist; but to make the subject as complete as possible, it will be briefly noticed. As soon as the goods enter the bleacher's establishment it is necessary, to prevent confusion afterwards, that each lot should be marked with the owner's name, so that at the termination of the work little difficulty may present itself in delivering the goods. With this view a person takes each piece, and stamps on one end the name of the owner with a brand of wooden letters dipped in coal tar, a body that remains unacted upon during the usual operations. By washing well with soap and rubbing between the hands, however, it will ultimately be obliterated. Some finer qualities of goods, instead of being marked with this material, have the initials or full name inserted in some indelible coloured thread, or with nitrate of silver, as the case may be.

The several pieces are then stitched end to end, in order to facilitate the subsequent bleaching.

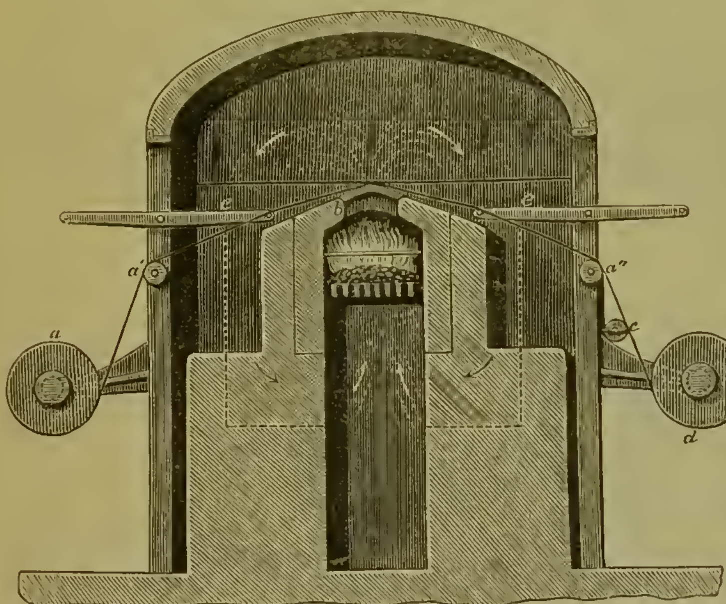
Singeing.—This operation is, like the above, a preparatory one, and consists in singeing or burning off the loose fibres or flocks on the surface of the cloth; were these permitted to remain they would very much injure the appearance of the bleached goods. The usual method of performing this part of the work is to pass the work over red-hot rollers at such

a velocity that the body of the threads is uninjured, although the loose fibres are consumed.

A few years ago J. HALL, of Nottingham, proposed to effect the singeing by drawing the cloth over the open flame of gas, and the process is said to have worked well; but of late it has almost entirely gone out of use.

The apparatus employed for singeing is represented in Fig. 3. The cloth, which is wound upon the revolving drum, *a*, passes over the guide-roller, *a′*, and is thence drawn across the red-hot plate, *b*. A second guide-roller, *a″*, brings it next in contact with a cylinder, *c*, which partially dips into water, and thereby extinguishes all sparks before the cloth is drawn upon the cylinder, *d*. Two frames, *e*, are so arranged that by their means the cloth can be brought into greater or lesser proximity to the plate. The plate is heated from below by an open fire, and the vapours produced are drawn off from the covered singeing space by two flues.

Fig. 3.



Goods which are to be printed with superior patterns and colours must be singed on both sides; ordinary goods, which come undyed into the market, are often not singed at all.

In some factories the singeing takes place after the bleaching; but the general experience seems to point to the advisability of giving precedence to the former operation.

Scouring.—The goods are next submitted to soaking and scouring. This operation requires some art as well as knowledge to perform it satisfactorily. Everything depends here upon an uniform soaking of all the parts, and this could only slowly be obtained if the cloth were thrown into the water in regular folds. To avoid such an expenditure of time the pieces are drawn through a tubular ring, the diameter of which is one-fourth or one-third of the width of the cloth, whereby they take the form of a rope; they are then coiled up, tied by a string to prevent their becoming loose, and thrown into a cistern. They remain here until they get thoroughly penetrated, after which the water is drawn off and replaced by some of 120° to 140° Fahr. (48°·8 to 60° C.), wherein the goods are left for thirty-six hours, during which time the glutinous matter of the size enters into fermentation; this process must, however, be checked as soon as it has reached the proper limit, for, if allowed to go on without restraint, putrefaction would ensue, which would finally attack and destroy the fibres of the cloth. Many bleachers dispense with the fermentation altogether, and prefer boiling the goods repeatedly in weak milk of lime or alkaline lyes. In the case of muslin goods, however, preference is generally given to the fermentation method, on account of the perfect manner in which it eliminates the gluten. After the decomposition the pieces are washed or scoured in a vat, either by the dash-wheel or some other convenient apparatus.

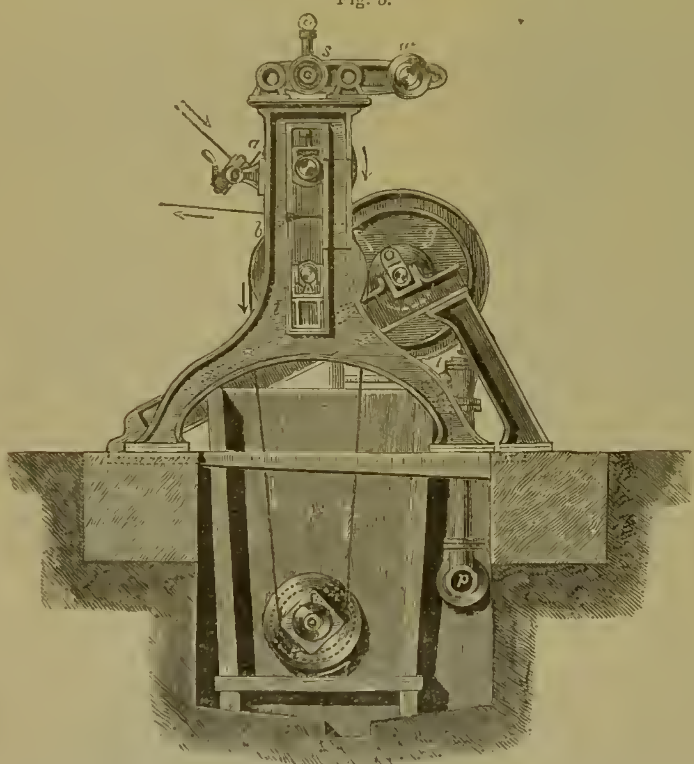
Fig. 4 is a drawing of the dash-wheels. A cylindrical box, of about 6 feet diameter and $2\frac{1}{2}$ feet depth, revolving upon its own axis, is divided by two vertically intersecting perforated plates into four divisions. Each of the divisions is provided at the front with an opening, through which the pieces of cloth are introduced, whilst the water enters on the opposite side. The wheel is set into slow motion, causing the cloth to toss from side to side, and thus washing it thoroughly in eight to ten minutes.

Fig. 4.

A scouring machine of still greater effect is that constructed by C. MATHER. Fig. 5 represents a lateral, Fig. 6 a front view of it. By this machine the cloth,

the ends of which had been joined to one another, is taken several times through water, and after each passage squeezed between cylinders in order to separate by friction the particles of impurity. The cylinders *a* and *b* are of wood (usually pine); *a* is about 8 feet long and 1½ foot in diameter, *b* of the same length, but 2 feet in diameter; the middle portion of the upper cylinder is thickened by a strong piece of cloth, *a'*, the purpose of which is to increase at that spot the pressure of the cylinders upon the goods; *c d* is a wooden beam provided with plugs, which conduct the piece in spiral lines from the upper cylinders to the cylinder *r*, and from this back again to the upper two; *h h* is the water trough in which *r* is fixed; *p* is a water pipe, provided with a valve, *t*; *m m* are two rings of glass or hard wood, fixed upon movable holders on both sides of the machine,

Fig. 5.



which serve to regulate the tension of the cloth. The levers, *w*, press the upper cylinder, *a*, against the lower, *b*, and they govern thus the amount of pressure exerted upon the cloth passing through the cylinders; the screw, *s*, is capable of increasing the effect of the levers. In the operation the piece passes through the eye, *m*, over the cylinder, *a*, round this between *a* and *b*, over the beam, *c d*, through the water in *h h* round *r*, from whence it ascends across the back of *c d* to the upper cylinders, and repeats this way in the direction of the arrows, until it finally leaves the machine at *a'*. It is obvious from the accompanying diagrams that two lots of goods are simultaneously washed in the apparatus, which enter on left and right sides, and leave it together at *a'*.

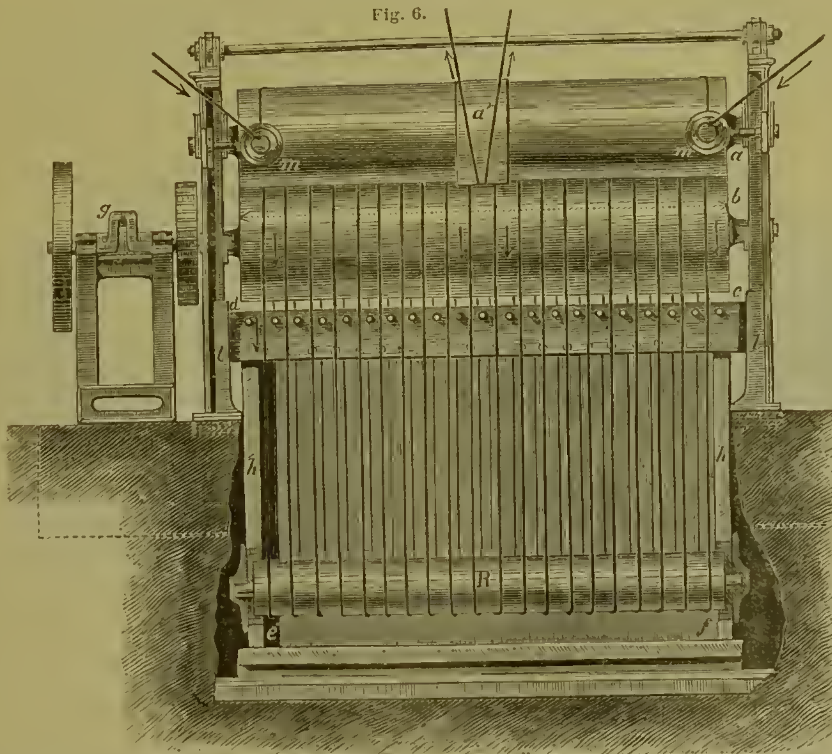
This machine is capable of scouring 800 pieces (of 35 yards each) in an hour, and requires only about 200 lbs. of water for every piece.

Bucking.—The boiling or bucking with alkaline liquids has for its object the abstraction of the small portion of the fat naturally present in the fibre, and also that casually added; likewise, the removal of the residual portions of the gluten. For a long time potash and soda lyes were used for bucking the goods, but at present lime is used, and is found to answer admirably, in consequence of its energetic action upon fatty matters, forming with them an insoluble calcareous soap. It is not known who first employed it, but it encountered a great deal of opposition. It was contended that it destroyed the fabric, that it formed with the fatty bodies insoluble soaps, which could not be washed away, and, worst of all, that the lime soap united with the colouring matters, and thus gave the goods a dark appearance. But none of these objections are valid; the first can only happen through an immoderate use of lime; the second difficulty is got over by decomposing the lime soap with an acid; the last grievance is true enough, but is still no grave impediment to the use of lime, since the dark colour is easily destroyed during subsequent operations. The treatment with lime has the advantage that the resinous coating is removed from the fibre, and that consequently the chlorine has ready access to the latter. Experiments have shown that the strength of the cloth is not injured by being boiled with lime water for two hours; it is necessary, however, that it should be of a certain strength, and likewise that the pieces of cloth should be covered over with the lye, stirred repeatedly during the boiling, and washed immediately after being taken out, in order to prevent the absorption of carbonic acid, which would form carbonate of lime on the cloth, and thereby destroy it in a great measure. It has been also observed, that ebullition in water, or in a soda lye, marking 3° Twaddle, or 1·015, at a pressure of ten atmospheres, notwithstanding that the alkaline liquor may, during the boiling, acquire double the density which it originally possessed, does not affect the goods; neither are they injured by boiling under atmospheric pressure in a lye of 1·070 specific gravity, or 14° T.; or by being immersed in a solution of bleaching powder, capable of decoloring three times its volume of a test solution of sulphindigotic acid for eight hours, and by being afterwards dipped in sulphuric acid of specific gravity 1·067 or nearly 14°; or by being steeped for eighteen hours in hydrochloric or sulphuric acid of 7° T. As a rule, however, the bleachers seldom employ solutions of the

strengths specified, since the weaker liquors yield equally good results.

The boiler, or "kier," in which the bucking is executed, is either one in which the lye is in contact with the goods, or one which receives its lye from a separate vessel. Formerly the kiers were heated directly by the fire, and such is still the case in smaller bleaching establishments; but in all large

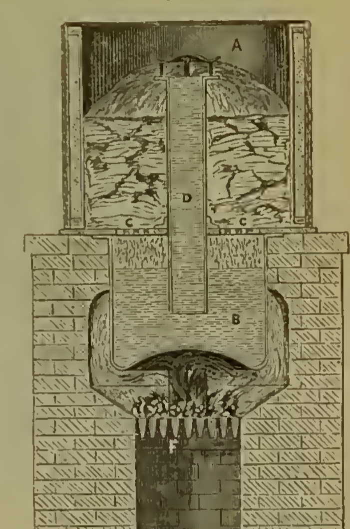
Fig. 6.



works steam is employed for the heating of the lye. The simplest kind of boiler is represented in Fig. 7. This kier consists of two principal parts, one, A, is the large receptacle for the cloth, and the lower part, B, is the boiler where the lye is submitted to the action of the fire. There is a communication between these two parts at C C, which consists of a strong iron or copper grating. In the middle of this grating a pipe, D, is firmly screwed; through this the lye in the lower pot ascends during the boiling. It is surmounted by a cap, by which the ascending liquid is made to spread over the goods, and return to the pot to be again heated. The upper part of this kier may be constructed of wood or sheet iron, well riveted and joined to the lye-pot; the latter may be of copper. As the object is to have an elevated temperature, the top vessel is shaded with a casing of wood, between which and the boiler is packed sawdust, charcoal, or some non-conducting material, so that no reduction or loss of heat may be experienced by conduction or radiation. F is the grate whereon the fire which heats the whole rests.

On applying the heat, the liquor in the lower vessels does not boil till the temperature exceeds 212° Fahr., but as the pressure is less in the pipe, D, in the course of a short time the liquor contained in it reaches ebullition, and steam is generated, which rushes out at the top, whilst the expansion of the body of liquid causes a column, more heated and denser, to rise, which throws that already in the pipe out upon the cloth. In this way the operation is conducted, a continuous stream falling upon the cloth, and percolating through the grating into the boiler, where it takes up a fresh portion of heat, and reascends as before.

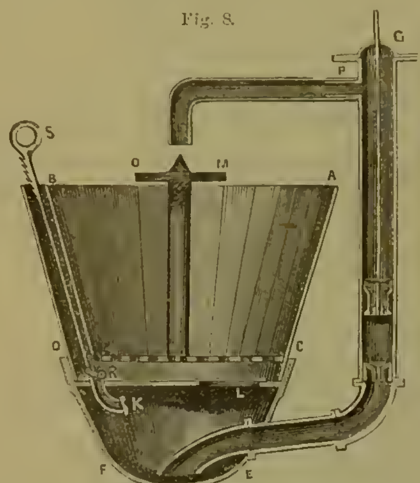
Fig. 7.



Sometimes the end of the pipe, D, reaches midway between the grating and real bottom of the lye-pot, and the boiling is continued as in the preceding case. Eight hours' boiling is the usual period for the completion of the first bucking, but this is sometimes prolonged to ten and even fifteen hours. At the conclusion the spent lye is drawn off by a pipe and stopcock at the bottom of B, and the goods are removed to the souring machine.

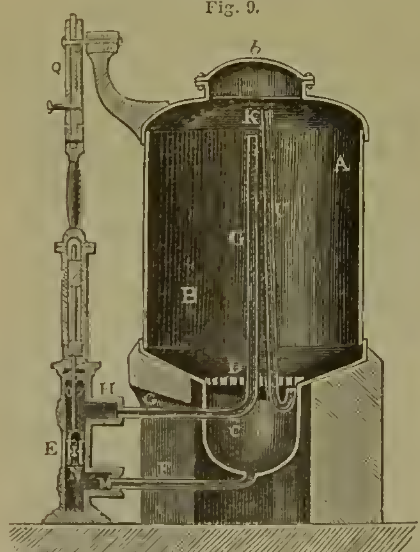
Laurie, of Glasgow, modified the foregoing apparatus in the manner represented in Fig. 8. A B C D is a large wooden tub, or "kier," into which the cloth is put, and which is firmly fixed at C and D to a copper or cast-iron boiler, C E F D, as seen in the drawing, wherein the lye is contained: it is covered lightly by a plate of the same material, a communi-

Fig. 8.



cation being made by means of a pipe, K, between it and the top vessel. A pump, G, is in connection with it, by which the liquid is raised and discharged upon the goods in the kier through the pipe, P. M O is a metallic plate upon which the pumped lye falls, and is dispersed all over the cloth. The whole is heated by a furnace as in the preceding.

Fig. 9.



The cloth is placed upon a movable frame or rack, and introduced into the upper vessel; the fire is then lighted, and while the contents of the lower vessel are reaching ebullition, the pump is kept in action; but after the lye begins to boil, the elasticity of the vapour keeps up the current, and the pump is no longer worked. As the liquor falls through the cloth, it returns to the boiler by the pipe, K, the valve, R, attached to this pipe, being opened by means of the handle, S.

Similar in principle is the apparatus of A. Robeson, of Newport, U.S., represented in Fig. 9. A is a copper vessel, divided by a perforated plate, D, into two compartments; E is a pressure pump connected by the tube, F, with the lower division, C; the tube, G, passes from the valve chamber, H, of the pump through compartment C, very nearly to the top of the upper division, B, where its mouth is covered with a concave disc, K. L and M are the valves of the pump, N the piston, O the piston-rod, which is set into up and down motion by the excentric disc, Q. The tube, R, which is provided with a safety valve, S, conducts steam from a boiler into the upper part of A. A tube, U, runs parallel with G, into compartment C, ending a little below the perforated disc, and is provided at this end with a small safety valve.

The goods to be bucked are laid around the tubes G and U, in the chamber, B, to the height of the latter tube. The lye is placed into chamber C, which can, if required, be heated. By working the pump the lye is pressed against the deflector, K, whence it is spread over the fabric. On allowing steam to enter through R, the lye will be driven right across the goods down into C. If the pressure of the steam becomes too great, the valve at the lower end of the tube, U, opens, and then the steam enters the lye in C, where it condenses.

The spent lye is removed from C by a tap (not shown in the drawings); the goods and the lye are introduced into the cylinder by the circular opening *a*, which afterwards is closed with the cover *b*.

The kier represented in Figs. 10 and 11 has been devised by Graham. It is about 8 feet in diameter by 6½ in depth, and is heated by steam injected through a pipe from a high-pressure boiler. The central pipe is about 8 inches in diameter; it is surmounted by a cap, against which the liquor is forced by the pressure of steam from beneath, and distributed over the goods. The kier, when in use, is secured by a well-fitting cover and screws, and any excess of elastic vapour which may have accumulated during the period of bucking, which generally lasts fifteen hours, is carried off by a pipe inserted into the shoulder of the kier.

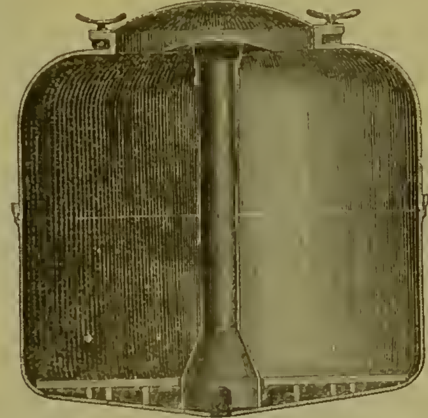
An improved form, devised by R. Kay of Busby, Renfrewshire, of the preceding apparatus, is shown in Fig. 12. The bucking cylinder, A, is the same as in Graham's arrangement; its top opening is closed during the scouring with the cover B. The vertical steam tube is connected with the cylinder at the bottom through the tube C, from which a pipe, E, provided with a tap, branches off in a lateral direction, by which arrangement the tube C serves a twofold purpose: it conducts steam into the cylinder, and takes away from it the spent lye. The circular false bottom, G, is perforated by rectangular holes, and has in its centre a large opening, to which the tube H is fixed; this tube becomes, a little above its joining, narrower, and rises to near the top of the cylinder, where its opening is surmounted by a screw, I, to which a valve, K,

is fixed. The valves can be adjusted higher or lower.

The goods are packed round the tube, H, up to near the upper end of it; the valve, K, is screwed down upon the mouth of the tube, H, and the cover, B, is put on. On tap D being opened, steam enters, and ascending through G, moistens the fabric. When the goods have become thoroughly saturated, the steam is turned off, cover B is removed, the valve K screwed higher in order to leave the mouth of H open, and the cylinder again closed with B. The goods are now ready for treatment with the lye, which is supplied to A from a kind of cistern, M, through pipe P; the lye is heated by steam brought into M through pipe O. Whilst allowing the lye to enter, the tap R is kept open for the escape of the air from A. When the liquid covers

Fig. 10.

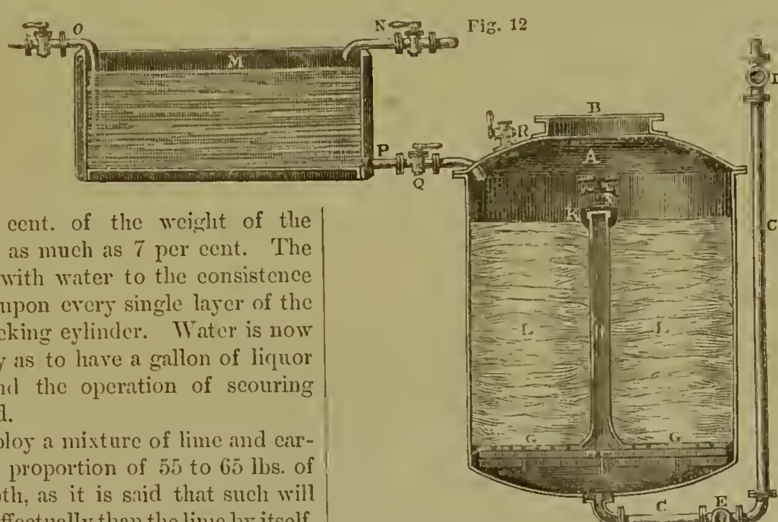
Fig. 11.



the goods, tap Q is turned off, and tap D again opened; the boiling lye is driven through H against the screw I, thrown from here down upon the goods, comes across these into the partition below the perforated bottom, and is now projected again through H to the screw, and so on.

When the operation is finished, the supply of steam is stopped, the lye drawn off, and the goods are removed through the opening at B.

Fig. 12



The quantity of lime employed varies: the ordinary proportion is about 3 per cent. of the weight of the goods, but some take as much as 7 per cent. The lime is slaked, mixed with water to the consistence of cream, and poured upon every single layer of the goods put into the bucking cylinder. Water is now added in such quantity as to have a gallon of liquor to 4 lbs. of cloth, and the operation of scouring carried on as described.

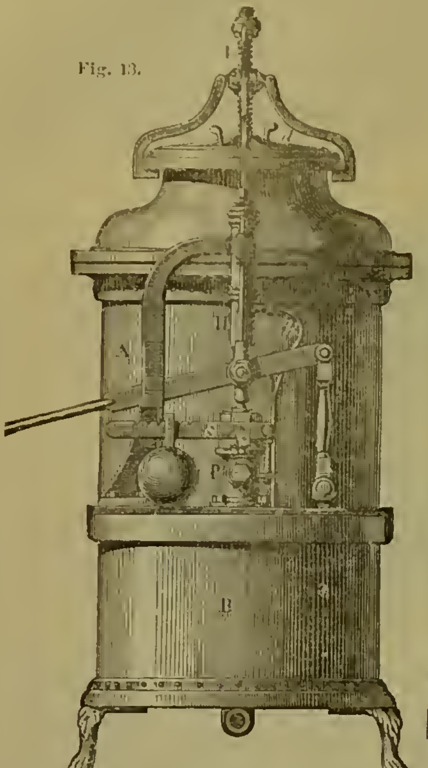
Some bleachers employ a mixture of lime and carbonate of soda, in the proportion of 55 to 65 lbs. of each to the ton of cloth, as it is said that such will scour the goods more effectually than the lime by itself. In this case the lime becomes inert, by abstracting the carbonic acid from the soda salt, and hence the caustic soda executes the work. CLAUSSEN uses caustic soda and lime.

It has been proposed to use, in the place of the caustic lime, a solution of lime in sugar. The advantages are said to be considerable: the fatty bodies are more easily saponified, the goods are certainly less affected, and the result of the scouring is such, as to do away, in some cases, with the necessity of treating with bleaching liquor. The goods are laid into a large vat, poured over with cream of lime, to which afterwards so much water is added that the liquor stands about a foot high over the goods; upon every 70 lbs. of fabric 1 lb. of lime is taken. The sugar-lime is next introduced, the vessel is closed, and heated for eight to ten hours under a pressure of $1\frac{1}{2}$ atmospheres. After boiling, the goods are washed, and again subjected to the above treatment. A second washing follows, and rinsing in hydrochloric acid bath, of $1\frac{1}{2}°$ B., makes the finish.

The sugar-lime is prepared by thoroughly mixing a milk of 50 lbs. of slaked lime in 108 lbs. of hot water, with 15 lbs. of molasses in 36 lbs. of hot water. One lb. of this mixture is used for about every 13 lbs. of fabric.

Metz, of Heidelberg, treats the goods with cold lye, as he believes the boiling to be injurious to the fibre; in his opinion, the only good of the boiling is the expulsion of the air from the interstices of the

Fig. 13.



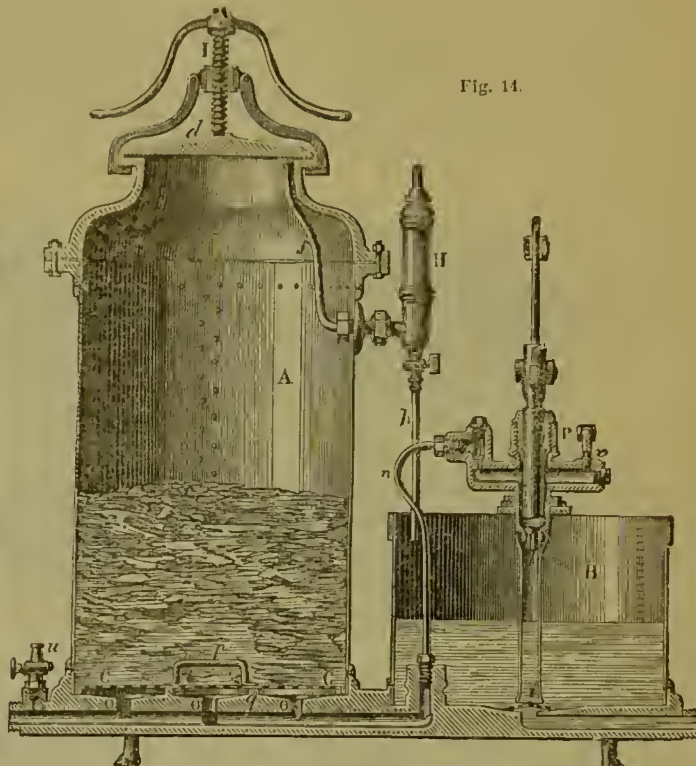
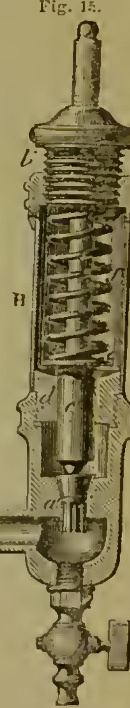


Fig. 14.

fabric. To effect this he proposes to subject the goods in the lye to great pressure. His apparatus (Figs. 13, 14, 15), consists of two vessels, or receivers, of a cylindrical form, made of tin or copper plates, and fixed upon one foundation. Into the larger of these, A, the materials are introduced through the opening at the top, and after that the cover, d, is firmly secured by the screw, I. A false perforated bottom, C C, placed in the interior of this cylinder, may be removed at will by the aid of a handle, p. All the air not retained mechanically, or in combination, passes off, during the filling of the cylinder with water through the pipe, O O O, at the bottom, by the pipe, f, which opens in the interior at the cover, d, and is joined at the other end to the indicator and regulator, H, in connection with the vessel, B. On a support, running across the top of this vessel, the pump, P, and its adjuncts are fixed; and this—by means of the suction pipe, l, perforated with small holes at i, so that nothing bulky can enter—forces the water through the pipe, n, and passages, O O O, into the vessel, A, containing the goods, and also into any others which may be in connection with it, as is shown by the continuation of the passage in the drawing. The pump has a safety-valve attached to it, as seen in Fig. 13 at x, weighted by the lever, S.

Fig. 15 is a sectional drawing of the regulator and indicator mentioned in the foregoing, and denoted by H. It contains a conical valve, a', which rising, presses against the lower end of the piston, c'; this works in socket, d, above which it has a collar, e', whereby it receives the pressure of the helical spring, f'; this causes it to butt against the top, b', screwed into the cylinder, and formed with a central opening for the passage of the piston-rod, c', graduated externally to show the degree of internal pressure; l' and i' show the corresponding parts in Figs. 14, 15. Before the air can escape, it must raise the valve, a', which cannot be accomplished unless the force determined by the adjustment of the spring is attained; hence it must escape by the pipe, h.

Fig. 15.



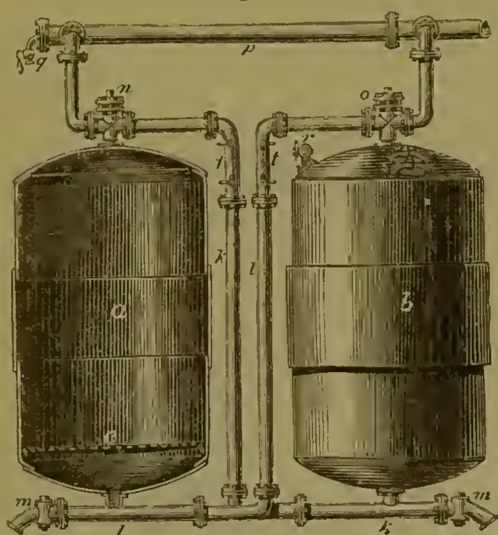
The operation is simple. The indicator is regulated so as to maintain a pressure inside the vessel, A, sufficient to expel the air, after which the material will be fit for the bleaching agents.

If it is desired to hasten the process of bucking the double kier patented by S. Barlow,* of Hakehill, near Middleton, is recommended. Fig. 16 shows the arrangement of these kiers. One of them, a, appears in section; c is a perforated bottom, upon which the goods to be bucked rest; the pipe, $k\,k$, connects the bottom of the one vessel, b, with the top

* His construction is essentially the same as that patented by him and J. Pendlebury in 1853.

of the other, *a*; pipe, *l l*, leads from the bottom, *a*, to the top of *b*; *m m* are taps, through which the spent liquor, &c., may be drawn off from the kiers; *n* and *o* are so-called two-way taps, by which the steam can be admitted into the respective kiers from the main pipe, *p*, and the reversing of which shuts off the steam communication, and admits the bowking liquor as it becomes expelled from the adjoining kier; *q* is a blowing-off valve; *r*, the pipe which brings the bowking liquor into the kier; *s*, the man-

Fig. 16.



hole (closed in the usual way by cross bars, secured by bolts and nuts), through which the goods are introduced and removed; *t t* are gauges by which it is ascertained when the liqnor has passed from one kier and has entered the other.

The process, one of the shortest and simplest, is as follows:—

The goods are run through a trough, usually the washing trough, half filled with milk of lime; they are carried forward by winches, and deposited in the kiers by a boy, who enters the vessel to lay the piece in regular folds.

When the kiers are filled, a grid of movable bars is laid on the top of the cloth, and the manholes are closed. High-pressure steam is then admitted at the top; this presses down the goods and removes the lime water, which is run off at the bottom. At the same time the air in the interstices of the fabric will be displaced by steam. Milk of lime—40 lbs. of lime in 600 gallons of water—is now introduced into the first kier in a boiling state. High-pressure steam is again admitted, which forces the milk through the goods to the bottom of the kier, then up the tube, *l*, and on to the goods in the second kier. The steam tap of the first kier is now turned off, and the steam sent into the second. The same process occurs, and the liquor returns to the first kier. The whole operation is continued for about eight hours. Upon 3500 lbs. of cloth, 1 cwt. of lime is required.

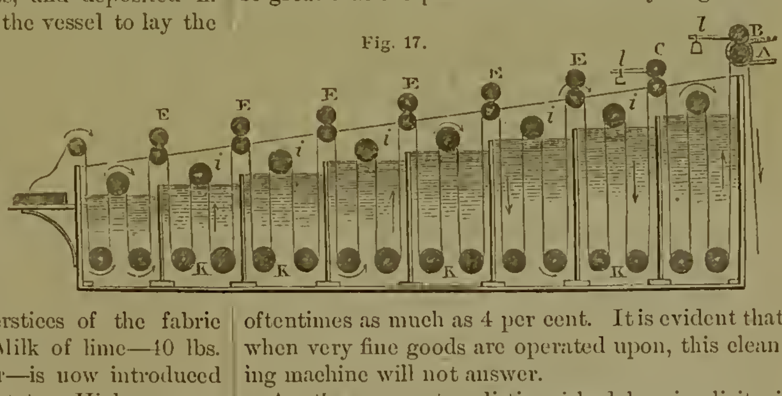
When the bucking with lime is completed, the steam pressure in the kiers is removed, the manhole opened, the grid taken away, and the cloth attached to the washing machine, which draws the goods out of the kiers, and washes them.

The apparatns is equally applicable for bucking with the caustic soda lye.

After the scouring has been completed, the goods are again washed, either in the dash-wheel or in one of the other machines for washing already described. The dash-wheel is very effectual, but requires skill in its management; for if its motion be slow, instead of the cloth being thrown against the opposite part of the wheel, it will slide down, and no detergent effect will follow; if, on the other hand, the movement be very rapid, the centrifugal force will cause the goods to circulate around with the periphery of the wheel, without ever falling against the sides as intended. Good results are obtained by twenty to twenty-two revolutions in the minute.

Where water is not in great abundance, the following arrangement (Fig. 17) has proved itself economical as well as efficient:—It consists of a number of vats of different depths, full of water, and snpplied with a constant stream, which flows into the nppermost, and thence into the next, from this to the third, and so on till it reaches the lowest vat, whence it runs off, carryiug with it the impurities of the scoured cloth. Within each of these vats or tanks guide and tension rollers, K K, are placed, and similar ones, *i i*, at the surface; the rollers, E E, are merely employed to squeeze the impurities out of the cloth as it passes out of the vat. Motion is communicated to the whole through the cylinders, A B and C D, which act also as squeezing aud traction rollers, and are kept in close proximity by means of levers, *l l*. By the use of this machine a considerable quantity of cloth is washed in a very short time, but the tensiou to which it is exposed is so great that the pieces are considerably lengthened, oftentimes as much as 4 per cent. It is evident that, when very fine goods are operated upon, this cleaning machine will not answer.

Fig. 17.



Another apparatus distinguished by simplicity is that of H. BRIDSON, of Bolton-le-Moors, Lancashire. Fig. 18 is a longitudinal, and Fig. 19 a transverse section of the machine. The body of the *washer*, A, is a cast-iron tank, kept half full of water; through the sides of this tank two horizontal transverse shafts, B C, are passed, and carried on bearings in the two

opposite side plates; they project from the side at B C, to carry corresponding spur-wheels, one of which is represented at E. By means of an intermediate driving shaft, which carries a wheel gearing into those upon B and C, the latter are moved in the same direction. B, C, have each a pair of discs, H I, Fig. 18, for holding the diametrically opposed parallel bars, J, which form the winces or revolving frames for acting upon the goods in the washing movement. The central shaft and wheel give motion to another superior wheel, K, fixed upon the axis of the lower roller, L, which, by moving in contact with another, squeezes the cloth. These rollers are of considerable size, and are supported by a pair of vertical standards, M, carried on a cross bar on the top of the cistern, which also bears a small standard for supporting the projecting end of the roller. The bottom roller is fixed, but the upper one is movable; means are furnished for adjusting them in the central vertical slot of the standard, M. In the longitudinal section, the course of the fabric, O, is shown round the guide roller, P, thence between the pair of nipping rollers, Q, set in bearings at one side of a division piece, R, and adjusted by handwheels and screws. After the cloth leaves these, it winds under the guide roller, S, and passes along between the first pair of vertical guide bars, T, then round the under side of the flat wince at the opposite end of the cistern; and returns in a parallel direction, moving in the same way over the bar, J J, of the discs, H I, and in the space between the second pair of division bars, T. In this way it continues its course, as seen in the transverse section, till it finally returns in contact with the wince bars, and passes up from beneath the guide-roller, U, set at the water level at the delivering end, over the external cylinder, V, and is delivered through the squeezing rollers, L, dry and clean. Two lines of fabric are operated upon at the same time, and therefore they follow the same course as that described.

The efficacy of this machine lies in the flapping or beating which the cloth receives from the revolution of the winces, during the time from its entrance till it passes out by V. This shaking and flapping or beating of the cloth on the surface of the water, and also the agitation of the lime immersed to bring it to the

Fig. 18.

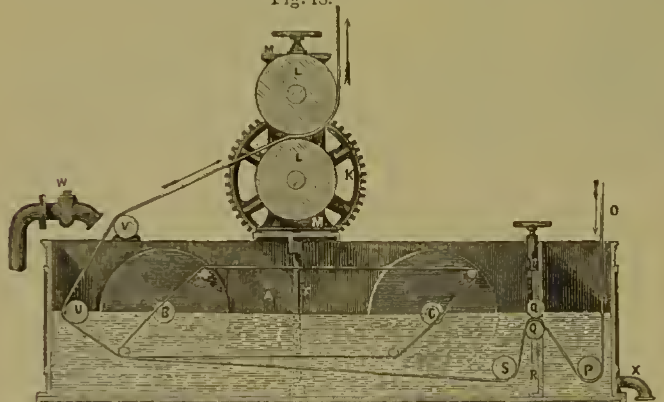
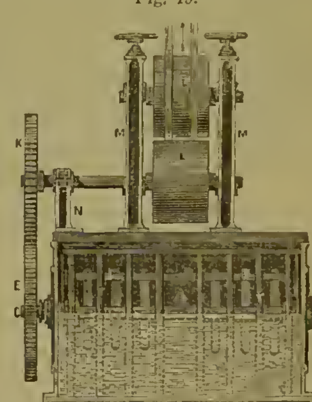


Fig. 19.



surface, have very great effect in detaching all the adhering impurities.

Souring.—This portion of the work, sometimes termed "chemicking," consists in immersing the goods, as they come from the preceding washing, in an acid solution. A gallon of strong sulphuric acid is added to 25 or 30 gallons of tepid water, and the whole agitated so as to intermix them thoroughly. This solution will have a density of from 1·047 to 1·040, and will contain from $6\frac{1}{2}$ to 7 per cent. of oil of vitriol. Many persons employ a very much weaker acid liquor, but prolong the time of immersion; the above solution, however, will not injure the fabric; but if considered advantageous, a weaker souring-bath be used. If it succeeds in decomposing the lime soap, the certainty of having the whole of the sulphate of lime formed dissolved out by the weak liquor, is greater than if the solution were concentrated. The time during which the goods are permitted to remain in the acid or souring-bath is generally four hours; but this is varied by circumstances, such as those mentioned, or by similar ones. After the souring, the goods are passed on to the machine, to free them from any acid that may have adhered to them, and also from any sulphate of lime, or lime salts, formed by the acid used during the decomposition of the lime soap.

Scouring with Caustic Alkali, and Washing.—The cloth is next submitted to a bucking in soda lye, made by adding about 2 lbs. of crystallized carbonate of soda, or about three-quarters to one pound of the dry carbonate to milk of lime, and stirring in order to causticize it, allowing the precipitated carbonate of lime to deposit, decanting off the liquid, and mixing it with from 5 to 10 gallons of water, according to the strength of the liquor to be used. Although pounds are here mentioned, in the large bleach-works the operations are conducted on such a scale that cwts. of the alkaline carbonate are deprived of their carbonic acid; but the proportion of alkali in the bath for bucking the goods nearly always remains the same as above mentioned. It is customary, by way of improvement, to add about 10 lbs. of resin to every 100 lbs. of soda ash, and to employ this mixture diluted as above, but without separating the carbonic acid from the alkali as in the

preceding. The resinous soap thus formed is said to act with greater vigour upon the colouring matters and other impurities of the cloth than the alkali by itself, as it enters into a soluble double combination which is removed with facility. The period of boiling with this lye extends to eight or nine hours, and after this time it is submitted to the washing machine, till all the soap formed with the fatty acids and any traces of alkali are removed.

In case carbonate of soda and resin are taken, as described, the boiling is kept up during fifteen hours.

We have arrived now at the bleaching proper. The preceding operations have removed from the fabric the mechanical impurities, fats, and resinous bodies, and have thus rendered the fibre accessible to the influences of the bleaching agent. Bleaching powder is the substance which is now almost universally employed for destroying the colour of the fibre. (The composition and probable mode of action of bleaching powder will be considered under Chlorine.) On immersing the fabric in the solution of bleaching powder no decolorizing effect, or at least none worth speaking of, shows itself; but the subsequent exposure of the cloth to the action of an acid leads to the desired bleaching of the fibre.

Every acid is capable of producing this reaction, even the carbonic acid of the air; but exposure to the air for this purpose is now never resorted to, the process being far too slow; dilute sulphuric or hydrochloric acids are employed, since they decompose the bleaching compound rapidly and effectually.

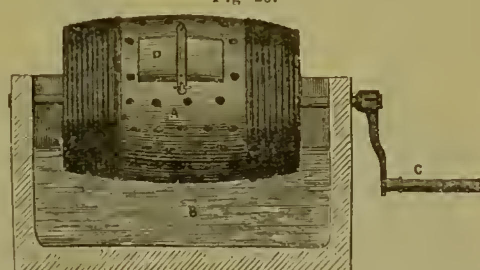
The question has frequently been raised whether it would not be more advantageous to use chlorine in the gaseous state. Past experience seems to be against it, but Persoz is decidedly of opinion that it would be preferable to employ chlorine in the gaseous state, since its bleaching effects upon the cloth would be exerted at once, without any of the subsequent processes and injurious effects upon the tissues, which are experienced when bleached by chloride of lime. He suggests a very eligible means for preventing its deleterious action on the workmen, by merely fitting up in the bleaching works a long funnel, which must be filled with chlorine gas; the pipe from the gas generator being introduced at the lower part of the funnel, so as to gradually displace the air. At the base of the funnel there should be a shallow vessel of water, to absorb any hydrochloric acid which may be formed. The pieces of cloth to be bleached might be introduced into the funnel through a slit made at the top of one of the sides; and by proper contrivances they would be made to circulate in the interior, so as finally to emerge at an orifice opposite to the entrance. Both these openings might be closed by water-lutes, to prevent any escape of the gas.

Bleaching with chlorine in water was also formerly practised; but both gaseous chlorine and its aqueous solution have long since given way to the much more convenient form of bleaching powder.

As bleaching powder does not destroy the colour of the fabric, it might be supposed that the immersion of the goods in a concentrated solution of it would not affect it injuriously; experience proves, however, that a piece thus impregnated, though at first not appearing to be injured, will very soon crumble into powder. The concentration of the bleaching bath is therefore of great importance. According to the strength and firmness of the goods to be treated, the density of the liquor ranges from 2° to 5° Twaddle; very fine fabrics are laid into very weak solutions.

The solution of the bleaching powder is effected in stone vats, wooden vessels being too rapidly attacked by it. To render its liquefaction more rapid and complete, a contrivance, such as that represented in Fig. 20, is employed. A cask, A, is partially placed into the vat, B, containing the solvent; it is traversed by an axis, at one of the extremities of which is a winch, C. The cask dips from 4 to 6 inches into the water in the vat, it is pierced with a number of holes, from one half to an inch in diameter, and contains a large opening, D, in one of its staves, closely covered over, serving for the introduction of the dry bleaching powder, together with some flints. The opening, D, being shut, the cask is put in motion by turning the winch, C, attached to its axis, and the flints or other pebbles,

Fig 20.

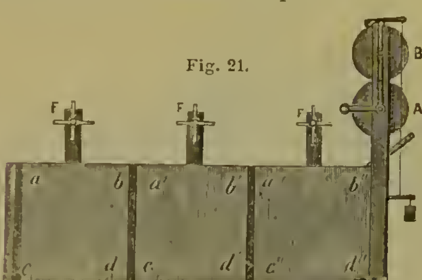


rubbing against each other, bray and pulverize the bleaching powder so as to promote its solution very rapidly. As it is of importance that the latter should be clear and transparent, it is allowed to rest till such substances as are held in mechanical suspension fall to the bottom. Without this precaution the goods are in danger of being seriously damaged, in consequence of the particles which are often found in commercial bleaching powder, and consisting of a basic chlorate, or some other compound not yet fully examined, being taken up in the cloth; these, when removed to the acid bath, will be decomposed with the evolution of so much chlorine or chlorous acid, or oxygen, as to produce holes in those places with which they had come into contact, the fibre being completely destroyed. Muslins, and such cloths as have an open texture, are very liable to this injury, if due care be not taken to prevent it. Schwartz refers to the chlorine disengaged from the compound as the cause of this; but Persoz differs from him, upon the ground that muslins may be exposed to gaseous chlorine, or to a clear solution of the bleaching material, without being in the least deteriorated. The latter chemist attributes the injury to the forementioned particles, having found that, if

bleaching powder be washed till all soluble matters are extracted, an insoluble residue is obtained, mixed with more or less lime and carbonate of lime, which when treated with hydrochloric acid, generates one of the most energetic oxidizing bodies; and when this is spread upon the fibre, and then the latter immersed in sulphuric acid, it is burned in numerous places. The necessity of having a clear solution is therefore obvious.

Treating with Bleaching Liquor.—The strength of the solution being regulated, the cloth is thrown into loose folds and immersed in it for a period of six hours. After it is thoroughly saturated with the liquor it is abstracted and immersed in the steeping vats, where it is left for six or eight hours; after which it is introduced into the acid liquor, prepared so as to liberate the bleaching element to exert its influence upon the goods. This constitutes the ninth process. But instead of the preceding, many adopt a somewhat different course. Sometimes the cloth is placed in a copper boiler, similar to those described under scouring, and the bleaching liquor is passed through it in the same way that the lye is circulated in the bucking; this method, however, is objectionable, as the cloth is liable to be only partially decolorized; and it is exposed to the great

Fig. 21.



danger of being injured by the boiler. The cloth is occasionally immersed in the solution for the proper period, and then left to remain exposed in the atmosphere of the room for some time, during which carbonic acid is absorbed, and the chlorine liberated to act upon the colouring matter of the cloth. After a certain time the goods are plunged into the acid solution, and here the whole of the bleaching element is set free. Again, many proceed by steeping a suitable quantity of cloth in a vessel adapted for the purpose, over which a roller is fixed. When the cloth has been immersed in the liquor for thirty or forty minutes, it is passed over the roller and suspended above the vessel till the solution ceases to drip off; it is then removed to the sulphuric or hydrochloric acid bath, over which it is hung, and the goods unrolled into the acid. Another process frequently resorted to is the following:—The cloth is placed for some hours in wooden troughs (Fig. 21) lined with lead, *a b c d*, *a′ b′ c′ d′*, *a″ b″ c″ d″*, which are filled with bleaching powder solution, and over which rollers, F F F, are fixed, for the purpose of communicating motion to the pieces, so as to increase their surface of contact with the solution. On withdrawing the pieces they are passed between the squeezing rollers, A B, placed on the side of one of the end vats, and the excess of the bleaching solution returns into the vat, *a″ b″ c″ d″*, by an inclined plane which is immediately under the rollers.

When it is desirable to perform the bleaching rapidly or continuously, a concentrated solution of the lime salt is taken, sufficiently concentrated to destroy the fabric were it to remain in contact with it for any length of time; and into this the cloth to be operated upon is introduced for a certain period, prolonged or abridged according to the strength of the solution, and afterwards passed between a pair of squeezing rollers, again re-immersed and afterwards pressed, till the fibre gets thoroughly imbued with the liquor. At this period the cloth is thrown into the acid-bath for the purpose of liberating the bleaching agent; and as more chlorine is disengaged in this case than when the solution is weaker, the tank is covered over to carry off the excess of the gas, so as not to obstruct or injure the workmen.

The bleaching liquor must not be of too low a temperature; 70° to 80° Fahr. (21°·1 to 26°·6 C.) is found to answer best, since at this temperature the solution easily enters among the pores of the fabric, and yet does not injure the latter.

Souring.—The concentration of the acid-bath depends entirely on that of the foregoing solution; has the latter been strong, then the acid-bath too must be of considerable strength, and *vice versa.* As a rule, 20 to 100 lbs. of sulphuric acid in 3000 lbs. of water, form the limits of the strength of the acid-bath; but of course there are frequent exceptions. The goods are left for three to four hours in this bath.

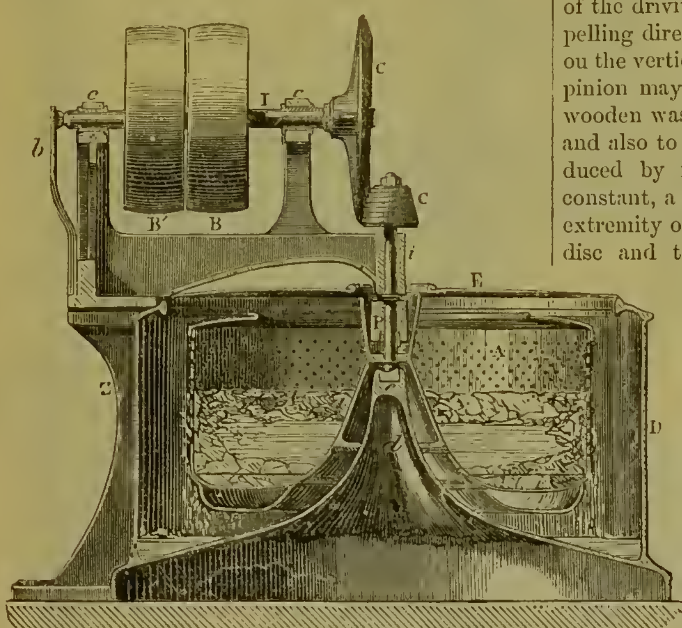
Before proceeding to the steeping in water, the goods are often subjected to pressure. This operation has a twofold effect: it frees the fabric from any excess of bleaching liquor, and next, it puts the remaining portion of the bleaching solution into a more intimate contact with the fibre of the fabric. Whenever goods are meant to be brought into the press, the strength of the bleaching liquor may without risk be increased, and thereby the time allowed for the goods to remain in the bleaching bath be considerably abbreviated. A machine, specially adapted for the purpose, has been constructed by C. Mather and W. Platt. It has two cylinders of the largest possible dimensions, made of hard wood, or only the upper one of wood, and the lower one of a compressed textile fabric. The axles of the cylinders are placed in a frame so constructed that the axle of the upper cylinder can, by means of a screw and a lever, be so adjusted as thereby to increase or diminish the pressure of the upper cylinder upon the lower one. A small steam engine sets the lower cylinder into motion; the upper cylinder is moved simply by friction. The fabric passes through the machine between the two cylinders, and the pressed-out liquor returns through a funnel tube into the bleaching bath.

Steeping.—The goods come from this press, or sometimes directly from the acid-bath, into cisterns filled with clean water, and are allowed to remain there for ten or twelve hours, after which they are rinsed,

in order to remove the lime-sulphate that has formed and settled upon the fabric in the two preceding treatments with bleaching liquor and the sulphuric acid bath. Part of the colouring matter attached to the fibre has by this time been eliminated; another portion has only been modified and still adheres, though now in a colourless state, to the fabric.

Bucking with Caustic Soda or its Carbonate.—To separate the decomposed colouring matter, the cloth is boiled in a lye of carbonate of, or caustic, soda during eight hours, in the same way as has been already mentioned: 60 lbs. of carbonate of soda, rendered caustic by maceration with quicklime and water at a boiling heat, is the quantity of alkali proportioned to 2100 lbs. weight of cloth; and also to every boiler of one ton capacity. After this operation has terminated, if the cloth is not

Fig. 22.



sufficiently white, it is submitted to one, two, or three subsequent immersions in a bath of the lime solution, then in acid, and again washed and reboiled in the soda lye, till the proper decoloration has resulted. The density of the liquors employed diminishes from the first immersion, according as the cloth is depurated.

Souring (3rd).—The goods pass again through a bath of sulphuric or hydrochloric acid, to prevent the recurrence of a more or less yellow colour, contracted by the action of the air upon the resinous matter of the cloth, which is only temporarily decolorized. This substance is insoluble in alkalies, but is dissolved by acids with the aid of heat. Besides the effect of dissolving the resinous substances, any traces of metallic oxides, such as iron, alumina, or lime, which may be present, and unless removed would materially affect the printing of the goods, are so modified that they can be entirely separated in the subsequent washing to which the goods are submitted.

Washing.—The resinous matters, &c., dissolved in the course of the previous operation, as well as the adhering acid, are removed by a final washing, with which the series of bleaching operations is concluded.

Drying and Mangling.—The goods have now, before being submitted to sizing, &c., to be freed from the water, and this is done by centrifugal machines or by pressing in mangles. Fig. 22 represents a machine worked by centrifugal force, constructed by Rohlfs & Seyrig. The driving shaft, I, mounted in the bearings, *c c*, of a standard fixed to the frame of the apparatus, and advancing to the centre of the top of the drum, A, carries two pulleys, B, B′, which are made to turn with great speed. The drum, A, must revolve at the rate of from 1200 to 1500 revolutions per minute. To the extremity of the driving shaft is riveted a conical disc, C, impelling directly by friction a conical pinion, C′, fixed on the vertical shaft which carries the drum, A. This pinion may be formed with leather, caoutchouc, or wooden washers, to prevent its being quickly worn, and also to avoid the noise which is commonly produced by rotation. That the pressure may be constant, a spring, *b*, is connected with the opposite extremity of the shaft, tending steadily to press the disc and the pinion against each other; a very smooth movement is thus obtained with perfect regularity.

The body, D, of the machine is connected by the binder, Z, with the basis or support of the apparatus, and at the same time with an interior enlargement, *d*, which sustains the socket, *e*, and the lower extremity of the pivot. The drum, or copper, A, which is attached to this pivot, and contains the goods to be operated upon, moves therefore along with it, and keeps itself in equilibrium, for it is placed in the same conditions as a balance; that is to say, the rounded pivot, P, is not encased in its support, and may assume all the positions due to the inequalities of the load being regulated by the force of rotation. The holes with which the drum is pierced, as shown in the figure, permit the water expressed from the goods by the powerful centrifugal action, to escape into the outer case in which the revolving drum is inclosed. The goods, when removed from this machine, are found almost perfectly dry.

Among mangling machines, that devised by More & Son of Glasgow is simple and highly effective. (Figs 23 and 24.) It consists of six rollers—three of compressed cotton, three of brass—fixed upon a cast-iron frame; the lowest roller is brass, the next cotton, and so on alternately. The pressure is applied to the rollers by a screw or lever on the top of the frame, and there is also another arrangement of levers for the three lower rollers, whereby the pressure may according to requirement be varied.

Fig. 23 is the end elevation, Fig. 24 a longitudinal view of the machine.

A. A. BASTAERT, of Paris, dries the finished goods by submitting them in closed chambers to the action of a mixture of heated air and superheated steam; goods so treated are said to be peculiarly soft and delicate to the touch.

Starching.—When freed from moisture by either of these methods, the pieces could be considered as finished, if the custom of purchasers did not insist upon demanding a glossy appearance which fabrics of cotton fibre do not possess. To meet this wish the goods are starched. This expression is rather a misnomer, inasmuch as starch proper is never used, being far too expensive. Flour is the substance chiefly employed, but the additions it receives are sometimes so preponderating as to reduce the proportion of the flour to the merest fraction. Fine porcelain clay and ground slate are the most usual admixtures, and it is by spreading mixtures of these substances with flour and water upon one side of the fabric and subjecting it to strong pressure, that they are incorporated with the fibre. To improve the colour of the starching or sizing mixtures, a

Fig. 23.

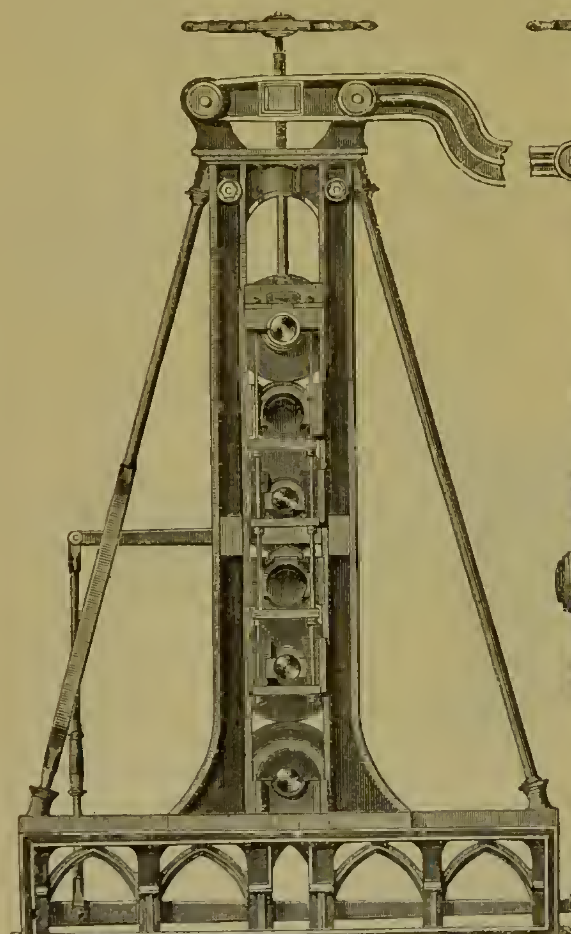
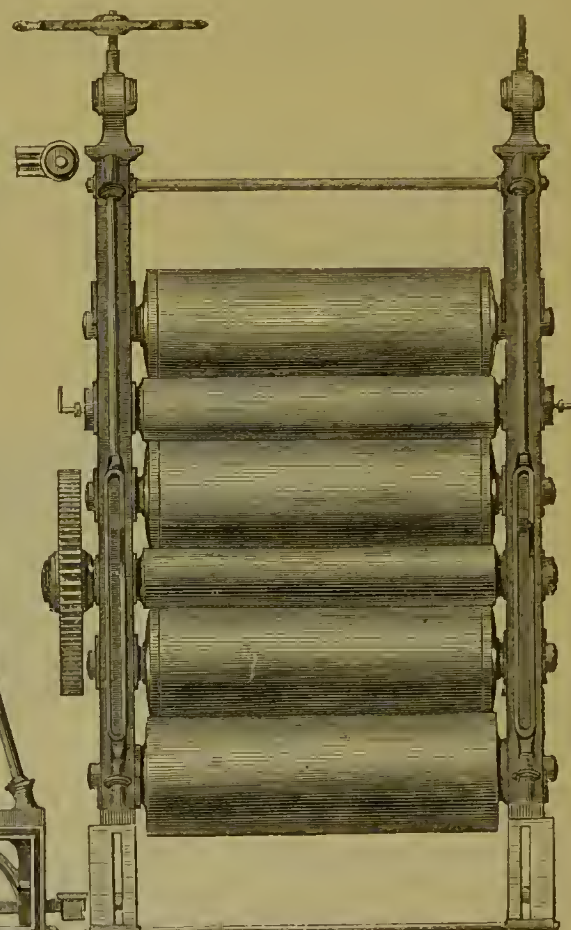


Fig. 24.



little indigo is added. The sizing and subsequent drying is accomplished simultaneously by a machine represented in Figs. 25 and 26:—A is the box containing the paste, which is used to starch or stiffen the goods; *a* is a winch, which can be employed to turn the machine by hand, although in large factories it is usually impelled by steam power; *b* is the driving pinion; *d d'*, two brass rollers with iron shafts, the lower of which is moved by the wheel, *c*, in gear with the pinion, *b*. The uppermost roller, *d'*, is turned by its friction with the other, which is pressed upon it by the weighted lever, *h*; *e* is the trough filled with the paste; it rests upon the bars, *f*, and may be placed higher or lower by means of the adjusting screws, *g*, according as the roller *d*, is to be plunged more or less deeply. A brass roller, *i*, serves to press down the cloth into the paste.

The drying portion of the machine is denoted by B. In this department, *k k* is the iron framing which supports the five drums, *l l l*; these drums are hollow copper cylinders heated by steam; *m m m* are small copper drums in pairs, turning freely on shafts under the former, for stretching and airing the goods during their passage through the machine; *n n* is the main steam pipe from which small copper tubes, *o o*, branch off into the superior drums. There are similar main

pipe and branch communications at the other end of the drums for discharging the condensed water, the pipes passing through air-tight stuffing-boxes. Whenever the steam becomes feeble, or it is necessary to turn it off, there are valves, $q\ q$, in the drying drums, which open internally to admit air, so as to prevent the collapsing of the cylinders, which the pressure of the atmosphere would occasion when they are exhausted; C is the cloth-beam from which the starching roller draws forward the goods; D are two rollers, of which the lower is provided with a band pulley or rigger, driven by a similar pulley fixed upon the shaft of the starching roller, d. These two rollers pull the goods through the drying machine, and then let them fall either upon a table or floor, as best answers. In this operation the cloth is either completely dried or left slightly damp, according to the wish of the operator: the former by communicating high-pressure steam to the drying drums; the latter by expediting the passage of the cloth, and introducing steam of a lower temperature.

Calendering, Folding, and Stamping.—The cloth passes over a sprinkling or damping machine, consisting of a circular brush, the tips of the hairs of which touch the surface of the water in a tank underneath; and by communicating a rapid motion to this brush, it discharges a shower of minute drops upon the piece as it is drawn from one end of the machine to the other. At first the moistening is partial; but after the cloth is permitted to remain in a heap for some hours, the dry parts absorb the excess of water from the wet spots, and the whole acquires a uniform dampness. The damp cloth is laid down in front of the calender—a machine greatly resembling the mangle represented in Figs. 23 and 24. It consists of a number of rollers running in a stout cast-iron

Fig. 25.

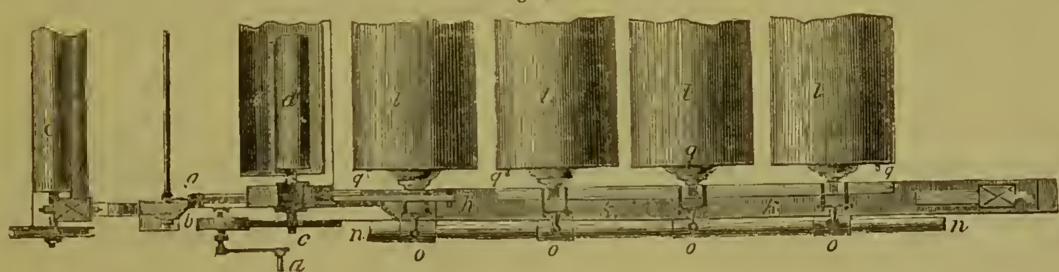


Fig. 26.

frame, and pressed together by weighted levers; the rollers are fixed parallel one over another, and bear a wheel gearing on their shafts to make them revolve. The smallest two of these rollers are of cast-iron, well turned and polished, and the large ones are made of paper. The cloth passes between the rollers, and is received upon a cylinder called the "batching" roller.

During the passage of the cloth over the rollers, its appearance is considerably changed. When it is drawn in a single sheet through the rollers, the threads are first flattened, but by going through the other rollers the fabric receives a peculiarly soft appearance. If, however, the sheets are double, or two sheets simultaneously are passed between the rollers, the threads of the one sheet make an impression upon the other, and both look wiry and hard. Through variations in the foldings, the appearance of the goods may be still further changed.

When the cloth has undergone all these operations, it is folded up, stamped with the peculiar brand corresponding to the standard of the market at which it is to be disposed of, and is ready to be sent to its destination. Should the calico be intended for printing at home, the latter process of calendering is not applied, and sometimes the starching is dispensed with, as it is only required in this case to have the natural colour of the fibre of the cloth removed. It is customary, however, to stiffen the goods, as this affords certain facilities in printing them. After the starching the cloth is folded upon a roller.

The preceding description represents the leading features of the process of bleaching cotton fabrics; but in practice great variations are introduced in the order of the single operations, their duration, &c. It would go beyond the scope of this Dictionary to give anything like a detailed account of the variety of

systems as now practised; but to show the difference in the methods of manipulation, a few shall be briefly sketched here.

The Grean Process.—*First stage—Scouring.*

(1.) Goods are immersed in a soda liquor of 2° (Gay Lussac) concentration (1 part of soda to 300 parts of water) during forty-eight to fifty hours.

(2.) Fulled and washed.

(3.) Treated for twenty-four hours with caustic soda of 12° strength.

(4.) Fulled and washed.

(5.) Placed for half-an-hour in a hydrochloric acid bath; 1 part of acid in 20 parts of water.

(6.) Fulled and washed.

(7.) Treated a second time with caustic soda, but of only 9° strength.

(8.) Fulled and washed.

(9.) Immersed in acid bath, as in (5.).

(10.) Third immersion in caustic soda lye, this time of 6° strength.

Second stage—Decoloration.

(11.) Immersion for three hours in bleaching liquor of 1°·5 of the chlorometer; repetition of this treatment for other three hours in a bleaching bath of 1°.

(12.) Treated with caustic soda lye of 4°, gradually raised to boiling, and maintained in ebullition for two hours.

(13.) Acid bath, as in (5.) and (9.).

(14.) Fulled and washed.

(15.) Immersion for three hours in bleaching bath of 0°·75 of the chlorometer.

(16.) Acid bath, composed of 1 part of hydrochloric acid in 300 parts of water.

(17.) Fulled and washed.

Grean was the first to lay down, as a principle, that the immersion of the fabrics in the bleaching solution should only take place when they are deprived of all fatty and resinous matters. His process is specially characterized by the fact that those impurities are gradually removed by repeatedly treating the goods with dilute lyes, and that the fabrics, after having been exposed to the action of the bleaching liquor, are first put into soda lye, and only afterwards into the acid bath; this treatment brings about the decomposition of the lime salt by soda, and the replacement of the lime by the latter.

The American Process.—*First Stage—Scouring.*

(1.) Bucking of the goods with lime from twenty to twenty-four hours. To 1000 pieces of cloth (three-quarters yard wide) 36 lbs. of fresh-slaked lime are taken, and instead of water, the residue of lye (3.).

(2.) Washing.

(3.) Repetition of operation (1.).

(4.) Washing.

(5.) Immersion in tepid sulphuric acid bath of 1° B.

(6.) Washing.

(7.) Bucking with soda carbonate: 2 lbs. of carbonate to every 1000 yards of fabric; residue of lye (12.) serves as solvent.

(8.) Washing.

Second Stage—Bleaching Proper.

(9.) Bath of bleaching powder, so dilute as to show no increase of density by the areometer, and to disengage no sensible quantity of chlorine on being saturated with an acid.

(10.) Hydrochloric acid bath of 2° B. strength.

(11.) Washing.

(12.) Bucking for twenty-four hours with carbonate of soda, 9 lbs. of carbonate for every 1000 yards of calico.

(13.) Washing.

(14.) Repetition of (9.).

(15.) Acid bath as in (10.).

(16.) Final washing and rinsing.

According to J. Tribelhorn and P. Bolley the hot bucking can be dispensed with by employing lyes containing stannic oxide. This oxide is obtained by adding soda carbonate to an aqueous solution of chloride of tin of 9° or 10° B. strength. The process is the following:—

(1.) Keeping the goods for twelve hours in tepid water.

(2.) Washing.

(3.) Immersion in a bath composed of 3 lbs. of the above tin preparation, dissolved in about 10 lbs. of caustic soda lye of 39° B., and diluted to 1° B. concentration.

(4.) Passing the goods through some mangling machine or press.

(5.) Sulphuric acid bath of 1° B. for half an hour.

(6.) Washing.

(7.) Immersion in weak bleaching liquor.

(8.) Steeping in sulphuric acid bath of 2° B. for three hours.

(9.) Washing.

(10.) Boiling with carbonate of soda solution of $1\frac{1}{4}$° B.

(11.) Washing.

If a high degree of whiteness is required the goods are further treated—

(12.) For four hours with bleaching liquor of $\frac{1}{2}$° B.

(13.) Immersed in sulphuric acid bath of $1\frac{1}{2}$° B.

(14.) Thoroughly washed.

In the "Continuous" system of bleaching the several operations already described are essentially the same; but the bath and other requisites are so arranged that the work may be continued regularly. The annexed sketch shows the general arrangement of the apparatus, as used by Graham, of Manchester, and from the perusal of the preceding details the whole will be readily understood.

Fig. 27 represents the arrangements. A is the boiler or kier, which may be similar to either of those described; B is the scouring machine; C, the souring and chemicking machine; and D, the steeping cistern. The course of the cloth from the boiler to the steeps, over the carrying winches, E E E E, and through the various machines, is indicated by the line, F F F F.

In Claussen's process the goods are first treated with carbonate of sodium and then with the bleaching liquor; hypochlorite of sodium and lime carbonate are

formed; the latter is decomposed in the hydrochloric acid bath, and is afterwards washed away as calcic chloride. When goods are to be dyed turkey-red, or in case of lime, CLAUSSEN employs hypochlorite of magnesia in the place of the ordinary bleaching compounds. The magnesia hypochlorite is prepared by mixing a solution of 2 parts of magnesia sulphate in 12 parts of water with one of 1 part of bleaching powder in 12 parts of water; sulphate of lime goes down, and magnesia hypochlorite remains in solution.

For goods which are to be printed with madder colours, or are to remain white, HIGGINBOTHAM & SONS, of Glasgow, use the following modification of CLAUSSEN'S process:—

Scouring.—Boiling for two hours in caustic soda lye of 1° T., to which 5 per cent. of quicklime has been added; soaking in soda carbonate of 2° T.; hydrochloric acid bath of 3° T.; washing.

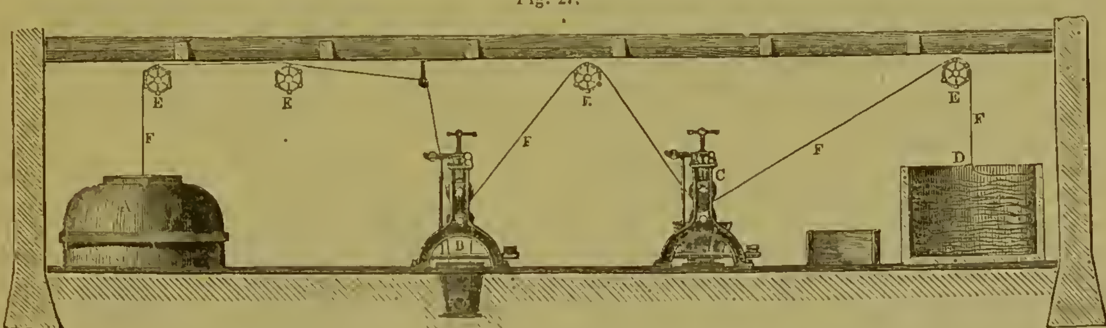
Bleaching.—Steeping in hot, but not boiling, soda carbonate liquor; immersion in bleaching bath of 3° T.; souring as before, and thorough washing.

Finishing.—Boiling half an hour in resin soap; immersing in the hot, but not boiling, bleaching liquor; acid bath as before, and final washing.

J. HIGGINS, of Manchester, has devised the following method of bleaching cloth:—About 3500 lbs. of cloth, after being singed in the usual way, are passed through a solution prepared by macerating about 224 lbs. of lime in a convenient quantity of water. When the cloth has been moistened uniformly with this liquid a further dilution with water takes place, and 2 or 3 gallons of bleaching liquor of 8° T. are poured in, and the whole boiled by steam for fourteen hours. After ebullition it is withdrawn, washed in water, and steeped in dilute sulphuric acid of 3° T., or hydrochloric acid of 2° T.; again washed with water, and folded in another kier containing a mixture prepared in the following manner:—Into an iron or other vessel put 30 gallons of water, 120 lbs. of soda ash, 80 lbs. of American resin or gum. Boil this compound by steam for eight hours, and then put in 25 lbs. of lime, made into a cream with water. Boil for six hours more and transfer to the kier, after which the cloth is folded in, sufficient water added, and the whole kept at ebullition for fourteen hours.

When the cloth is sufficiently boiled it is removed and washed with water, then steeped in or passed

Fig. 27.



through a bleaching solution marking 5° on T. It is then passed through sulphuric acid 3° T., or hydrochloric of 2°, and afterwards well washed.

In some cases it may be well to give the goods another boiling in a kier with soda alone.

When goods have been "limed" in BARLOW'S double kier (see Fig. 16) they usually undergo the following process:—

After the bucking operation is terminated, the manhole is opened, the grid removed, and the cloth attached to the washing machine, which draws the pieces out of the kiers and washes them.

The goods are then passed by winches through the souring apparatus, or are soured by having hydrochloric acid of 2° T. pumped upon them. They must remain with the acid two or three hours, either steeped in it or after having passed through it.

A new washing follows, and the cloth is drawn by winches as before through the washing troughs back into the kier.

Steam is introduced into the kier, the air and cold water are expelled (by the tap at the bottom), and a solution of soda-ash and resin is poured into the vessel; 224 lbs. of soda-ash and 150 lbs. of resin in 600 gallons of water for 7000 lbs. of cloth. The kiers are then masked for about eight hours, as before, by driving the liquid alternately from one cylinder into the other. If the cloth is very strong, or if it has been printed upon in the grey state, a larger proportion of soda may be used.

Another washing follows, and then immersion in the bleaching solution, which has previously been warmed up to 80° or 90° Fahr. The strength of the solution is about $\frac{1}{2}$° T., or 1·0025 specific gravity. When the bleaching is for finishing white, milk of lime is added to the bleaching powder solution in order to retard the action.

The bleaching operation is followed by washing, souring, and so on.

If the cloth has been well managed, it will almost be white when it leaves the second kier treatment, and will therefore require very little bleaching. The method has the undoubted advantage of quickness; eight hours only of bucking appear sufficient, and the whole course of operations may be performed in two days.

In bleaching muslins, fermentation, almost entirely abandoned in all other cases, is the first step. The goods are allowed to remain in the lye for about thirty-six hours at temperatures varying from 100° to

150° Fahr. They are next bucked with potash and soap; for 112 lbs. of muslin, 6 or 7 lbs. of pearl ashes and 2 lbs. of soft soap, with 360 galls. of water, are employed, and ebullition is maintained during six hours; the goods are then washed by the scouring machine; after which they are rebucked for three hours, with 5 lbs. of pearl ash and 2 lbs. of soft soap; they are again washed, and afterwards immersed in a clear solution of bleaching powder of 6° on the indigo test tube, and allowed to remain in it for from six to twelve hours, when they are washed and steeped in dilute sulphuric acid, 3°·5 Twaddle. The cloth is next well washed and boiled in $2\frac{1}{2}$ lbs. of pearl ashes, and 2 lbs. of soft soap, for half an hour; again washed and immersed in a bleaching solution as before, at a strength of 3° on the indigo test, and allowed to remain in it for six hours. After this the fabric is again washed and soured in sulphuric acid of 3° T., or spec. grav. 1·015. If the goods be strong, they will require another boiling, steeping, and souring. The sulphuric acid should be well washed out previous to the finishing operation with starch. Lime is occasionally taken for bucking muslins instead of alkali, the same proportion being used as above mentioned for the latter: the time of boiling, however, is not prolonged beyond fifteen minutes, lest the fabric might be injured.

From time to time attempts have been made to employ permanganates for bleaching purposes. TESSIÉ DU MOTAY and MARÈCHAL showed at the International Exhibition at Paris, 1867, goods bleached by permanganic acid. The bleaching liquor consists of a solution of an alkaline permanganate and magnesium chloride, in which the goods are left fifteen to twenty minutes. For 100 parts of the goods to be bleached 2 to 6 parts of permanganate of soda suffice. From the bleaching bath the goods pass into an aqueous solution of sulphurous acid, and are left there until all the oxide, which by reduction had been deposited on the fabric, is dissolved. The oxidizing and subsequent reducing operation is repeated until the goods have acquired the necessary degree of whiteness.

An important point in this method is the cheap preparation of the permanganate. The above-named French manufacturers take the manganic oxide, resulting from the immersion of the goods in the bleaching bath, fuse it with nitrate of soda, and pass atmospheric air through the molten mass; the manganate of soda which is formed is dissolved in water, and transformed through addition of magnesic chloride into permanganate.

Experiments conducted on a large scale in VERLAY'S establishment in Comines (France) have shown that flax yarn is completely bleached by this process in twenty-four hours, and linen in only three days.

This rapid bleaching is, however, in the opinion of experienced bleachers, not trustworthy; it is suspected of affecting injuriously the fibre.

BLEACHING OF FLAX.—The bleaching of linen differs in many respects from that of cotton goods. Linen is manufactured from the fibre of the flax plant, *Linum usitatissimum.* (Fig. 28.) The plant is composed of three principal parts; the wooden centre, known by the term *shore* or *boon;* next to this the fibrous substance, which, when separated, constitutes the flax; and a thin outer membrane enveloping the whole. The fibres, when separated from the stem and the outer envelope, appear under the microscope as long, narrow, cylindrical, hollow tubes, not flat, and somewhat stiff. (See Fig. 2.) Their width averages from $\frac{1}{100}$ to $\frac{1}{150}$ of a millimètre. Tinctures of iodine and sulphuric acid colour it fine blue; concentrated sulphuric acid dissolves it. The flax plant has to undergo a peculiar treatment in order to separate the fibres from the stem and the envelope. The fibres are held together, and also firmly glued to the inner stem, by a kind of gum, the chemical nature of which is as yet very little understood. But the

Fig. 28.

relation of this agglutinating substance to various solvents is tolerable well known, and this appears for practical purposes sufficient enough. Alkaline lyes readily dissolve the different compounds of which this gum seems to be made up, but they are nevertheless not applicable on the large scale on account of their being too expensive. A cheaper process, which, however, requires longer time, is resorted to for breaking up the gum. Among the bodies contained in the agglutinating substance there are found several forms of albuminous matter which bring about a kind of fermentation when the flax stems are left for some time in contact with water. This fermenting process, termed *retting*, is carried out in four different ways—cold water retting, tepid water and steam retting, dew retting, and mixed retting. Before the retting, the flax is submitted to

mechanical treatment, chiefly in order to remove the seeds, and in many cases also the roots; we do not propose to enter into this part of the process.

Cold Water Retting.—The raw flax is tied in bundles, after having previously been sorted according to length, the bundles are then placed in perforated wooden chests, or in a kind of lattice-work basket, and these are finally immersed in a pond, or a specially prepared pit filled with water. Retting in rivers, formerly practised to a great extent, is now avoided, since the flowing water carries off those constituents of the fibre which contribute to bring about the fermentation. The present mode of cold water retting is now almost universally carried on in pits of 4 feet depth, lined with brick or stone, and provided with a feeding and an outlet pipe for the water. The bundles, having the fibres with their roots to one end, are packed with the roots downwards into the chests, and are covered with boards weighted down so much with stone, as to keep the flax below water, but yet allow it to float. In the warm season the fermentation sets in very soon, and becomes apparent from the dark colour of the water and the disengagement of gas bubbles. A slow stream of water is now turned on and permitted to percolate the mass. An oversight in this matter leads easily to the destruction of the fibre—the fermentation of the glutinous substance passing into putrefaction of the fibre itself. In very hot weather, and still more when the atmosphere is charged with electricity, such changes may happen very suddenly. The operation, requiring, according to the season, from five to twenty-one days, is to be regarded as finished as soon as the central stem of the plant breaks easily between the fingers, and readily separates from the surrounding fibres. The flax is now washed, rinsed, taken from the pits, spread in thin layers upon a meadow, and left there to the influence of the air and the sun for several days. As soon as the surface appears dry, the stems are tied again at their upper ends, and spread with their roots in a circle, in order to give free access to the air. By this means the drying is sufficiently well accomplished; but sometimes the flax is piled up in heaps, which are covered with straw, and thus further exposed to the air.

The gases evolved during the fermentation—chiefly carbonic acid, but also ammonia, marsh-gas, and no doubt ammonium sulphide—are highly disagreeable and even injurious; the fishes perish in ponds in which retting operations are performed. To diminish the escape of these gases into the atmosphere, the bundles are taken from time to time from the retting pits, immersed in water containing $\frac{1}{4}$ per cent. of sulphuric acid, and then put back into the pit.

Dew Retting.—In this case the moisture of the atmosphere, in the form of dew and rain, is utilized for inducing and supporting the fermenting process.

The flax stems are spread in thin layers upon a meadow, and allowed to remain for eight to ten weeks. It is necessary in dry seasons to water the flax to prevent excessive drying.

Mixed Retting.—This is a combination of the foregoing methods. The bundles are left in the water until the beginning of the fermentation, and then spread in a wet state upon the meadow.

Steam Retting.—There are several methods for treating the flax with tepid water, and they all have that in common, that the vat containing the flax and the water is heated by steam introduced from a separate boiler. In Schenk's process the water is gradually brought to 80° Fahr., the admission of steam being regulated in such manner as to raise the temperature of the water every hour only by 1°, and in order to secure this the temperature of the liquid in the vat has constantly to be tested by a thermometer. When the fermentation is finished, which usually is the case after sixty-four to sixty-eight hours, the flax is washed by allowing water to enter at the bottom of the vat and permitting it to flow away through a pipe near the top; if the wash water were conducted downwards, the resinous impurities would remain between the flax bundles, these acting as a filter.

The following is the course of the fermenting process:—

(1.) Water colours brown, and gets gradually darker, without, however, passing into dark brown.

(2.) The liquor, which had for several hours remained clear, becomes turbid, and evolves gas bubbles of faint aromatic odour.

(3.) The evolution of gas becomes stronger, and a mass of scum covers the surface of the liquor.

(4.) Formation of a pellicle which conglomerates the scum bubbles.

(5.) Increased gas delivery, which breaks the scum pellicle at different spots, and sets it into wavelike motion. The gas contained in the large bubbles is without odour, and explodes when approached with a light.

(6.) Gradual decrease of the evolution of gas and the formation of scum; change in the odour of the gas, which, however, has not yet become unpleasant; increase in the formation of the mucous pellicle, which at the same time becomes darker.

(7.) Apparent cessation of the reaction. Quiet formation of a new, snow-white yeast-like scum, which breaks here and there through the pellicle, and, where it cannot do so, lifting it up, and thus giving the surface of the retting liquor an undulated appearance. Along with this the odour becomes exceedingly unpleasant. The fermenting process is now at its climax.

(8.) Pellicle continues to become darker, and the white scum disappears.

(9.) The pellicle commences to break up, so that the turbid brown liquor becomes more and more visible.

(10.) The torn pieces of the pellicle, as they float on the surface, begin to disappear; the process is finished.

The vats are often covered and provided with pipes for the drawing off of the unpleasant gases.

The drying of the retted flax is performed either by means of centrifugal machines, or the bundles are spread out flat, the fibres fastened in the middle between two wooden rods, and thus hung up in

large airy barns, which are heated up to 100° or 110°, not more; in summer the temperature of the atmosphere suffices to dry the flax in about two days.

The flax is, after drying, stored away for six to eight weeks before it is submitted to the action of machines, in which the separation of the fibre, the flax proper, from the woody constituents is effected.

Recent experience has led back to cold retting; the operations are, however, carried on in vats which can be heated by steam, &c., but the temperature of the retting water is, as a rule, kept only at 70° to 80° Fahr. (21°·1 to 26°·6 C.).

That, however, the elimination of the impurities is more thorough in tepid water than in cold water retting is apparent from the following table, in which HODGES has given the result of his analyses of flax retted according to SCHENK'S method (1 and 2) and of flax retted in cold water (3). He found in 100 parts:—

	1.	2.	3.
Wax, resin, volatile oils, and acid,....	2·200	2·620	2·3
Sugar and colouring matter, soluble in alcohol,..........................	1·541	0·624	7·59
Gum and pectin bodies,.............	0·698	0·280	
Caseine and nitrogenous matter, soluble in water,.......................	3·560	1·386	6·50
Nitrogenous matter, insoluble in water,	2·940	4·310	
Inorganic matter, soluble in alcohol,..	0·281	0·116	1·05
Inorganic matter, insoluble in alcohol,	0·076	0·041	
Inorganic matter attached to the fibre,	0·238	1·490	
Vegetable fibre, ...	87·974	89·136	82·56

POWNALL subjects the flax, as it comes from the retting vats, to squeezing between iron cylinders, whilst he allows at the same time a stream of clean water to flow through the material. This operation removes adhering impurities, and also loosens the connection between the fibres.

SCRIVE proposes to interrupt the retting process every six or eight hours, and then to wash the flax in tepid water. This method is said to be advantageous, in so far as it brings about a more uniform action of the retting liquor upon the flax; but it requires large masses of warm water, and lasts considerably longer than SCHENK'S process.

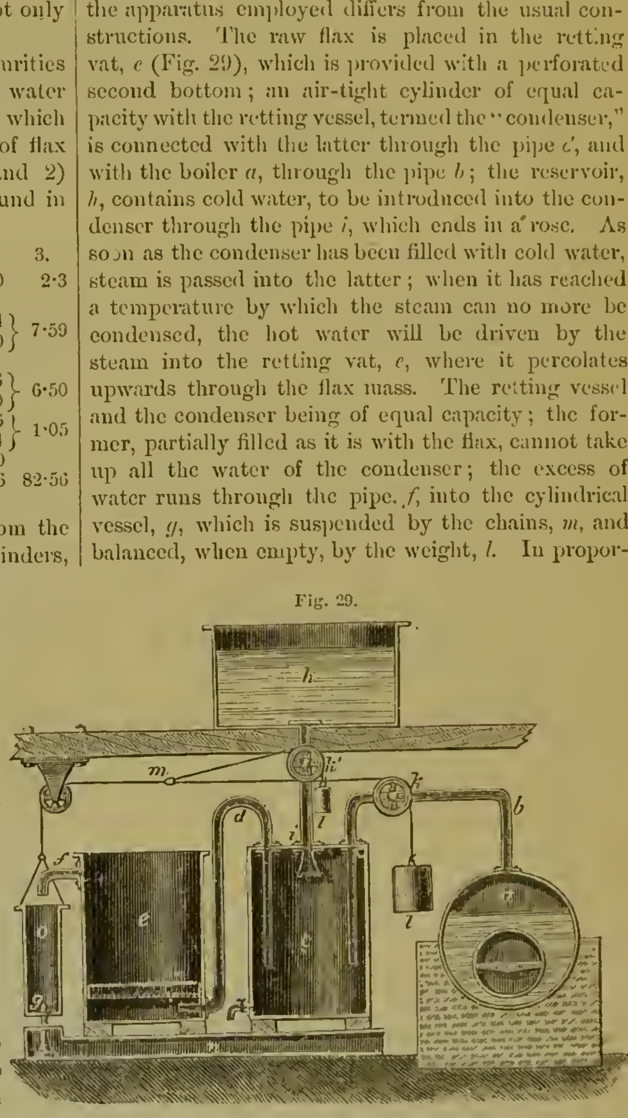
TERVANGNE adds finely powdered charcoal and chalk to the retting bath, in order to bind the gases evolved during fermentation.

BURTON and PYE pass the flax through squeezing rollers before introducing it into the retting vats, and they submit it then to the action of water of 85° Fahr., to which some fuller's earth had been added, for thirty hours, press it out, and wash and rinse it with clean water, which is gradually raised to a temperature of 150° Fahr. After washing, the material is again subjected for four hours to a heavy pressure. This second forcing, as well as the first, is performed in the vat itself, which is cylindrical, and into which a circular board, touching the sides of the vat, fits.

Essentially different from all others is WATT'S method, inasmuch as the flax is not made to undergo any fermentation. The flax is placed while dry in a cylindrical vessel, provided with a false bottom, and steam is passed into it from below; the steam condenses between the fibres and brings, in flowing down, the impurities with it. This steaming requires only twelve hours, certainly never more than twenty-four. After this preparation, the flax is passed through heavy rollers which deprive it of 80 per cent of the water absorbed during the straining; the remaining moisture is removed by drying the material under airy sheds.

Similar to the foregoing is BUCHANAN'S method, but the apparatus employed differs from the usual constructions. The raw flax is placed in the retting vat, *e* (Fig. 29), which is provided with a perforated second bottom; an air-tight cylinder of equal capacity with the retting vessel, termed the "condenser," is connected with the latter through the pipe *c'*, and with the boiler *a*, through the pipe *b*; the reservoir, *h*, contains cold water, to be introduced into the condenser through the pipe *i*, which ends in a rose. As soon as the condenser has been filled with cold water, steam is passed into the latter; when it has reached a temperature by which the steam can no more be condensed, the hot water will be driven by the steam into the retting vat, *e*, where it percolates upwards through the flax mass. The retting vessel and the condenser being of equal capacity; the former, partially filled as it is with the flax, cannot take up all the water of the condenser; the excess of water runs through the pipe, *f*, into the cylindrical vessel, *g*, which is suspended by the chains, *m*, and balanced, when empty, by the weight, *l*. In proportion as the cylinder, *g*, fills with water, it will sink, pull the chain which passes over the pulley, *k*, to the top of the steam pipe, *b*, and in so doing shut off the steam. At the same time another chain, joined to *m*, and passing over the pulley, *k'*, will open the tap of the water pipe, *i*, and allow cold water to shower into the condenser. The cylinder, *g*, in descending, reaches finally an iron rod, which, by being thus pressed, opens a valve in the cylinder, and allows its contents to run off through the pipe, *n*.

Fig. 29.



The sudden condensation of the steam produces a

vacuum in the condenser, in consequence of which the water from the retting vessel will rush back. The cylinder, *g*, having become empty, is again pulled up into its original position through the weight, *l*, and causes thereby the chains to run in an opposite direction, and by doing thus, opening the steam tap and shutting off the water cock. The water in the condenser is again heated by the steam until the latter will no more condense in it; it will then be driven into the retting vat, and so forth. This operation is repeated ten to twelve times, and seldom requires more than four hours, after which the flax is in good enough condition for further treatment.

The drying of the flax is performed in the apparatus itself; all the water is let off through taps, and hot air blown through the retting vat; the air is heated in flues which are placed in the chimney of the boiler fire.

This process is distinguished by its being so wholly independent from manual labour, and also by its allowing great masses of raw material to be worked up in very short time; but its drawback is, that the same water is used repeatedly for the extraction of the impurities.

The process of bleaching goods made of flax resembles on the whole that of cotton fabrics, but it differs greatly in the details. It appears that the colouring matters of flax require repeated exposure to air and atmospheric ozone before they become so transformed that they can be destroyed by chlorine. Cotton goods may already after two or three washings and buckings be brought into the bleaching bath; but if such proceedings were adopted with linen, it would have the effect of rather fixing the natural colouring matter upon the flax, instead of removing it. The linen is therefore repeatedly treated with alkaline lyes, and between each treatment it is spread out on grass and left there for several days.

The proportion of impurities to be eliminated from the flax fibre is considerably greater than that of cotton; the latter loses in the whole of the bleaching operation about 5 per cent. of its weight, whilst the loss in flax amounts to 30 per cent. It has been tried, with a view to shorten the time required to remove this large quantity of impurities by employing lyes of high concentration, but in all such cases the fibre itself proved affected. In the methods generally practised weak lyes are used in frequent repetitions; this makes the process of the bleaching of linen somewhat tedious, usually twenty to sixty days being required for it.

The following examples are intended to convey an outline representation of some of the most usual methods of linen bleaching:—

I. Irish method without croft bleaching.

(1.) Steeping in weak alkaline lye for thirty-six hours, and washing.

(2.) Bucking for six hours in a lye of 60 lbs. of caustic soda in 900 gallons of water, and washing.

(3.) Steeping for about fifteen hours in bleaching liquor, the strength of which varies according to the quality of the cloth, and then washing.

(4.) Immersion for six hours in acid bath (hydrochloric or sulphuric) of 3°·5 T., and washing.

(5.) Bucking for four hours in caustic soda, as in (2.), and washing.

(6.) Put for fourteen hours into bleaching bath, as in (3.), and washed.

(7.) Souring in sulphuric acid bath for ten hours, and washing.

(8.) Rubbed with brown soap upon a board, and washed.

II. Irish method with croft bleaching.

(1.) Steeping for thirty-six hours in weak alkaline lye, and washed.

(2.) Boiled with 60 lbs. of pearl-ashes (crude potash carbonate), washed, and exposed on the grass during three or four days.

(3.) Bucking with 80 lbs. of pearl-ashes, washing, and exposure on grass as before.

(4.) Bucking with 90 lbs. of pot-ashes (refined potash carbonate), washed, and crofted as above.

(5.) Bucked with 80 lbs. of pot-ashes, &c.

(6.) Bucked with 60 lbs. of pearl-ashes, &c.

(7.) Steeping in sulphuric acid bath, and washing.

(8.) Bucking with 60 lbs. of pearl-ash, washing, crofting for three or four days.

(9.) Immersion in bleaching bath, and washing.

(10.) Acid bath, washing, exposure on the grass.

(11.) Boiling with 30 lbs. of pearl-ashes, washed, laid out on grass.

(12.) Boiling with 20 lbs. of pearl-ashes, &c., as in (11.).

(13.) Acid bath, &c., as in (10.).

(14.) Rubbed with brown soap upon a board, washed.

The weights in the preceding two methods refer to the working up of 360 pieces of cloth, of 35 yards each.

III. Old Bielefield method, with exposure on grass, and without bleaching powder. Time required, fifty to sixty days.

(1.) Fermenting, fulling, and washing.

(2.) Exposing on the grass, with frequent watering, for three days.

(3.) Bucking five to six times successively, in caustic lye, by increasing temperatures from 135° to 195° Fahr., for six to eight hours.

(4.) Exposing, after preceding washing, upon grass, as in (2.).

(5.) Bucking and exposing on grass are repeated five times in succession.

(6.) Souring in a bath containing 1 part of concentrated sulphuric acid, or two parts of hydrochloric acid of 22° B., to 100 parts of water. In winter the bath is slightly warmed. The goods remain in it for six hours, and are then washed.

(7.) Bucking as in (3.), but with the temperature raised to about 205° Fahr.

(8.) Crofting as in (2.).

(9.) Rubbing with soft soap.

(10.) Bucking as in (7.).

(11.) Exposing on the grass for two days.

(12.) Bucking as in (7.).

(13.) Exposing as in (11.).

(14.) Souring in a bath of whey, or sour milk, for eight to ten days, and washing.

(15.) Exposing as in (11.) and (13.).

The last two operations, (14.) and (15.), are, if necessary, repeated until the goods have acquired the required degree of whiteness.

IV. German method for quick bleaching. Time, six days.

(1.) Fermenting, fulling, and washing.

(2.) Boiling for two hours in moderately strong caustic potash, fulling, and rinsing.

(3.) Steeping for four hours in bleaching solution of 2° B., and washing.

(4.) Sulphuric acid bath and washing.

(5.) Exposing on grass for twelve hours without watering.

The process is repeated in this order until the desired whiteness has been obtained.

V. Quite recently C. HARTMANN of Heidenheim, has described a process which is said to yield a white of the highest quality. The course is the following:—

(1.) Steeping for forty-eight hours in water of 80° to 90° Fahr., and washing.

(2.) Drying in centrifugal machines, or otherwise.

(3.) Boiling for four hours in caustic soda of $2\frac{1}{2}°$ to 3° T., and washing.

(4.) Drying.

(5.) (6.) Boiling in caustic soda, as in (3.) and (4.).

(7.) Immersion in bleaching bath of hypochlorite of soda of $\frac{3}{4}°$ to 1° T., for ten to twelve hours, and washing.

(8.) Exposing on the grass for eight days.

(9.) Bucking with caustic soda, &c., as in (3.)

(10.) As in (8.).

(11.) As in (7.).

(12.) Crofting for four to six days.

(13.) (14.) Bucking, &c., as in (3.) and (4.).

(15.) Bleaching bath, &c., as in (7.).

(16.) Weak sulphuric acid bath, and washing.

(17.) Drying.

It is peculiar in this method that there is only *one* souring to three immersions in the bleaching bath.

VI. Chevalier CLAUSSEN employs magnesia sulphate for bucking purposes, and magnesia hypochlorite solution for bleaching. The process is the following:—

(1.) Boiling for two or more hours in caustic soda of 1° to 2° T.

(2.) Steeping in magnesia sulphate solution of 40° T.

(3.) Steeping in carbonate of soda solution.

(4.) Sulphuric acid bath of 2° T.

(5.) Washing.

(6.) Boiling with soda carbonate.

(7.) Immersion in magnesia hypochlorite.

(8.) Steeping in soda carbonate.

(9.) Acid bath as in (4.).

(10.) Washing.

(11.) Boiling half an hour in solution of resin soap.

(12.) Steeped, not too hot, in magnesia hypochlorite of 2° T.

(13.) Acid bath as in (4.) and (9.).

(14.) Washing.

In BOUCHARD'S continuous process, the pieces are attached to one another endwise, and carried by rollers to a double metallic casing, heated by steam; from this the cloth passes into a steam-bath, and emerging from whence, it passes round the opposite corresponding part of the double metallic casing, and is then smoothed in its course over different rollers. It is dried and dressed by its passage over a great part of the surface of a drum or cylinder of large diameter, which follows the preceding series of rollers: this large double-cased cylinder or drum is heated by a current of steam. The cloth, by embracing its circumference, is dried and dressed; and these operations are completely finished by the passage of the goods over other rollers, and between a pair of squeezing cylinders. After undergoing this pressure, which is the last operation in the process of scouring, the cloth is deposited on a stretching table, as at first, on which it is folded and put up.

Fig. 31. Fig. 30. Fig 32.

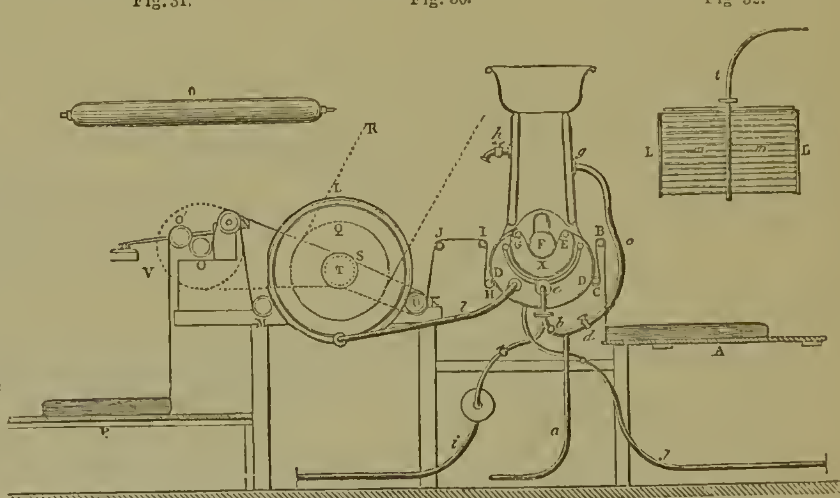


Fig. 30 is a longitudinal section of the machine employed; it measures about 6 feet in width, to adapt it to cloth of all sizes.

The goods in one long web lie on the table, A, placed on the right of the machine. In the first place the cloth passes round the roller, B, then descends round the inferior roller, C, and rises again bearing on the outer surface of the double-cased reservoir, D. The goods then continue their progress, passing round the roller, E, and the cylinder, F, from which they ascend to the roller, G, and again, in descending, bear on the opposite corresponding sur-

face of the double-cased vessel, D. Leaving this, the cloth is conducted round the roller, H, and then, round the rollers, I J K; thence it proceeds round the large double-cased drum, L, and then from the larger roller, M, it rises to the upper roller, N, and finally passes between the squeezing rollers, O O′, from which it is again laid down on a stretching table, P, at the end of its course.

In this mechanical contrivance, the continual taking up of the cloth results from the transmission of the movements in the following manner:—Q is a pulley, which by the strap, R, receives motion from the prime mover. From the axis of this pulley the motion is communicated to the roller, K, and to the squeezing cylinder, O, by means of the pulleys, S T U V. Thus the continual taking up of the cloth is effected by the roller, K —and when necessary, by the roller, M — and by the squeezing-roller, O; the pressure of the upper roller, O′, on the inferior one, is regulated by a weighted lever. One of these squeezing rollers is represented in Fig. 31.

The steam is admitted into the double-cased vessel, D, by the pipe, *a*. This pipe is connected with two branches, *b* and *c*, the former being fitted with a stop-cock, which serves to allow the steam to enter the cylinder, *e*, at pleasure; this cylinder is perforated over a part of its lower circular surface, and in its whole length, with small holes, so as to force the steam from the cylinder to pass within the double casing by these holes. The steam thus introduced into the vessel, D, first heats the outer case, then penetrates into the interior, X, in which are placed the hollow metal rollers, E F G. This concavity is a steam-bath, to which the steam passes by small holes perforated at its base; it is here that the goods are submitted to the penetrating action of the steam. From this basin, which occupies the whole extent of the reservoir, D, the steam issues into the iron double-cased chimney, *g*, to escape upward.

The steam likewise arrives into the casing, *g*, by the branch, *c*, which is also furnished with a stop-cock, *d*; and it maintains the elevated temperature of the chimney, which is fitted with another stop-cock, *h*, required for working the apparatus. On the side opposite to that at which the steam enters, it issues out by the return pipes, *i* and *j*, to be again conveyed in any direction.

The large double-cased drum, L, is supplied with steam by the branch, *l*. This drum consists of an outer casing of copper and an inner cylinder of cast-iron; it is furrowed with circular grooves or channels, *m*, over its whole length, as represented in the horizontal section, Fig 32; there is likewise a longitudinal canal, which communicates with all the circular channels. By this arrangement the steam circulates equally within the double casing, so as to diffuse the heat perfectly over the whole circumference, and throughout the entire extent of the surface. The steam escapes by the pipe, *t*, from the side opposite to that by which it entered.

Tessié du Motay's permanganate process has already been described.

The preceding description of the retting and bleaching of flax applies also closely to the treatment of hemp, the fibre of *Cannabis sativa*, a plant belonging to the family of the *Urticæ*.

Besides cotton, flax, and hemp, there are yet several other vegetable fibres which enter into the formation of textile fabrics. The operations required for their purification and bleaching differ in no essential part from that of flax; as a rule the lyes and the bleaching liquor used are of greater concentration. The principal fibres of this class are China grass (*Urtica nivea*), jute (*Corchorus capsularis*), both of which are imported from India, New Zealand hemp (*Phormium tenax*), Manilla hemp (*Musa textilis*), and the cocoa-nut fibre.

Bleaching of Wool.—Wool is composed of very fine filaments, the external surface of which presents the appearance of transverse corrugations. Under the microscope (Fig. 31), each fibre appears as a nest of thimbles, one within another. Wood fibre is covered with a greasy matter, termed *yolk*, or *suint*, derived chiefly from cutaneous perspiration, but secreted partly by the pores of the wool itself. Chevreul found two kinds of fatty matter in wool suint; the one, called by him *stearin*, melts at 140° Fahr., and requires 1000 parts of alcohol for solution; the other, *elaierin*, melts readily at 55° Fahr., and dissolves in 143 parts of alcohol. None of the two are said to saponify. The same investigator found merino wool to contain.

Suint soluble in water,.........................	32·74
Earthy matter precipitating itself from the aqueous solution,.........................	26·06
Fatty matter soluble in alcohol,..................	8·57
Earthy matter fixed by the fat on the wool,.......	1·40
Wool fibre,.......................................	31·23
	100·00

The removal of this suint is the aim of the preliminary treatment to which the wool is subjected before the bleaching process is resorted to.

The older method, still used in many places, consists in immersing the wool, packed into a net, in a slightly warmed bath of putrid urine, about 1 part of the latter to 5 parts of water. When the wool has become thoroughly soaked with the liquor, the net is taken out, suspended for a short time over the bath, and then placed into a vat, through which a constant stream of clean water runs. It is important to avoid the stirring of the net in the urine bath, in order to guard against the wool fibres getting twisted into a felt. The same bath serves several charges of wool.

The effective constituent of the urine is the carbonate of ammonium, which results in the putrefaction from the decomposition of the urea. The ammonium carbonate is not capable of saponifying the fatty matters, but it forms an emulsion, which will mix with water.

Carbonate of soda solution was tried in the place

of the above bath, but was not found to answer; if, however, soap is used along with soda carbonate, very good results are obtained.

In 1857 CHEVREUL published a new analysis of the suint of wool, from which it appeared that the suint contained considerable quantities of potash salt. This observation led MAUMENÉ and ROGELET to patent a process for the recovery of the potash salts, and this process implies some modification of the scouring of wool. The material is thoroughly exhausted with water before it is submitted to the scouring with soap and soda carbonate solution.

Quite recently various solvents have been proposed for extracting the fatty matters. Bisulphide of carbon is found effective enough in bringing almost the whole of the fat into solution; but it seems to affect the fibre, to make it stiff, and impart to it a dark colour. It is reported, however, that a large establishment in Pomerania obtains satisfactory results by the use of this detergent.

Decidedly more successful is the process of P. TOEPLER & CO., in which impure amylic alcohol, ordinarily known as *fusel oil*, is employed for dissolving the fatty substances. The wool, previously exhausted with cold water, is treated in a tank with fusel oil, passed into a second tank filled with the same agent, and lastly washed with water, whereby the adhering oil is removed, such oil being slightly soluble in water. The wool is then freed from water by a centrifugal machine, or pressure in rollers, &c., and completely dried by exposure to a current of slightly warmed air.

The advantages of this process are said to be—

(1.) A larger yield of cleansed wool, the gain being almost 5 per cent.

(2.) Less "waste" in the subsequent operations of carding and spinning, and considerable lessening of the quantity of oil required.

(3.) From a given quality of wool, manufactured goods are produced which have the appearance of goods of a higher quality of wool, such wool being cleansed by the ordinary process.

(4.) With a given amount of plant, a larger quantity of spun wool can be made, as the carding engines, &c., require less frequent cleansing.

There are, however, two drawbacks to the use of this solvent. One is the great objection entertained by the neighbourhood, and sometimes the workmen themselves, to the use of great quantities of fusel oil; for though the vapours do not appear to be injurious, they are yet sufficiently unpleasant to make them intolerable. The second disadvantage is that unavoidable loss of oil must ensue in the operations, though the greater part is regained.

Caustic baryta and strontia have been adopted by DAUDENART and VERBERT, of Brussels, as substitutes for soda carbonate. The value of this process rests chiefly upon the cheap production of the cleansing agents.

One thing must be particularly guarded against in scouring wool or woollen goods, namely, the application of an elevated temperature, as it would affect the fibres, and cause them to felt more or less; the most favourable temperature for the scouring liquors is 60° to 65° F.

In scouring woollen goods it is imperative to keep them stretched during the time they are passing through the scouring liquor, otherwise they will contract unequally, and such shrinking will, of course, disfigure their appearance.

Fig. 33 represents a machine employed for that purpose. A A is a wooden frame-work; B, a vessel containing the weak lye or soap liquor for scouring the cloth; C C, two copper rollers which keep the cloth stretched, and at the same time deprive it of water; they are covered over with several folds of calico or paper, the better to express the moisture as the cloth emerges from the bath. The upper roller is provided with a lever, D, and counterweight, for increasing the pressure at will. E is a movable roller, working in a groove, on which the goods are wound, and which is intended to stretch them with greater or less force, according as the weight at the extremity of the lever, F, which is in contact with it, is made to act. G is a widening guide, with diverging grooves, to stretch the fabric before it arrives at the rollers, and prevent folding or overlapping. *a a a a* are small wooden cylinders, resting upon copper bearings; by these the goods are made to circulate in the lye for a certain time.

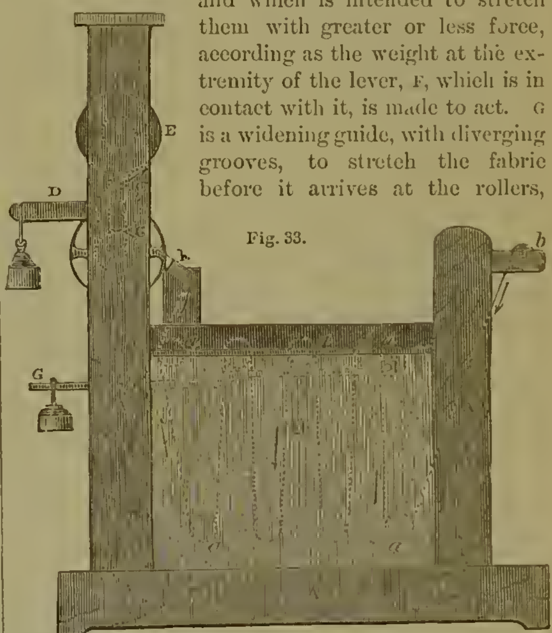


Fig. 33.

After the cloth is sufficiently impregnated with the lye, it is passed round the cylinders *a a a a*, and fixed—four, six, or more pieces, according to their length—over the cylinder at the point *b*. The working of the machine is carried on by putting one end of the web of cloth in communication with the traction rollers, *c c*, the remainder being passed into the vessel filled with warm water, and after circulating there for a certain time, coming to the squeezing rollers, C C, where it is divested of the most part of the liquid, and then folded upon the roller, E. After this the cloth is removed, to undergo either a new lixiviation or washing. When it is necessary that the last traces of the impurities of the filaments should be removed, the goods must

be repeatedly transmitted through the carbonate of soda lye, alternated with an immersion in a bath formed of carbonate of soda and soap.

CLAUSSEN uses a feeble solution of caustic soda for scouring, and when the fatty matter from the wool has formed a soapy liquid, he gradually and cautiously adds small quantities of caustic soda, so as always to have the scouring bath a little caustic. After this the wool is saturated with a solution of carbonate of soda, put in a weak sulphuric acid bath, and finally washed. For very fine qualities of wool, carbonate of ammonia is used instead of carbonate of soda.

The agent employed for bleaching wool and woollen fabric is sulphurous acid, and not bleaching powder. Sulphurous acid unites with the colouring matter of the wool to form a colourless compound, which remains adhering to the fibre. Bleaching by means of sulphurous acid is termed "sulphuring."

The acid is applied either in the gaseous state, or in aqueous solution. When employed in the gaseous state, a large chamber is provided, the door of which closes hermetically; this chamber is furnished with valves and openings for supplying the air, as well as for the admission of the ignited sulphur; there is also a series of strong upright planks fixed in couples at proper distances from each other, and studded with pegs, the extremities of which are enlarged, and have a notch near the end, in order to prevent the cloth which may be strung upon them from falling off. All the pieces of cloth being stitched together so as to form one length, it is passed round these pegs, being carried alternately from one to the other in a horizontal course. When the cloth is fixed upon all the pegs of the frame, the chamber is hermetically sealed, and the burning sulphur introduced by the openings at the base; these are immediately closed, and the combustion of the sulphur is carried on merely by means of the air contained in the chamber. When this is exhausted, the burning of the sulphur ceases, but the interior of the chamber is charged with sulphurous acid gas, which is taken up by the moisture of the cloth; and, being thus brought in contact with the colouring matter, as it insinuates itself into the pores of the fabric, it exerts its bleaching powers very effectually. It requires about twenty-four hours' contact with the cloth before all the colour is destroyed; and sometimes the air has to be renewed, and a fresh quantity of sulphur burned, before the work is completed.

The next method by which woollens may be bleached, is by employing the sulphurous acid in a state of solution in water; its action in this state is more regular and economical than when used in the gaseous state.

The gas is easily and economically prepared by heating sulphate of iron and sulphur to low redness in a close cylindrical vessel of earthenware; an exit pipe at the end of the cylinder would convey the gas to a vessel adjoining, which may be filled with moss or some porous matter that will not absorb the gas, but clear it from any impurities which may be carried off mechanically; thence the gas could be conducted to the water cistern where it is to be absorbed, and admitted into it till the solution is saturated. To insure the complete impregnation of the water, the gas, as it makes its exit from the cistern filled with moss, &c., above mentioned, could be admitted at the base of a tower of convenient height filled with small stones, pieces of earthenware, and the like, through which a stream of water may be allowed to percolate from a cistern at the top, by a series of small perforations in the upper slab of the tower. This water meeting the ascending current of gas would completely dissolve it, and flowing out into a proper receptacle at the base, could be drawn away as use required. Water absorbs, at the ordinary temperature and pressure, about forty times its volume of the gas, part of which it retains even after continuous boiling.

The liquid, when submitting the cloth to its action, should have a temperature of between 80° and 90° Fahr. (26°·6 to 32°·2 C.); but if the solution is completely saturated at a temperature of 60° Fahr. (15°·5 C.), then, if it were elevated to the above point, a large volume of the gas would be expelled, and prove a powerful obstacle to the success of the operation, besides involving so great a loss of labour and materials; to avoid this, all that would be required is to dilute the liquor, so that nothing appreciable will be evolved. The goods being immersed into the bath of liquid acid, are retained there till such time as by an examination they are found to be thoroughly bleached; they are then taken out, washed well with water, and, if deemed necessary, with a little potash or soft soap.

The following is an enumeration of the operations to which woollen stuffs are subjected during the bleaching. Forty pieces of cloth, of 45 to 50 yards in length, are taken and stitched endwise together; they are then singed as cotton goods, and treated as here described:—

(1.) Immersed three separate times in a bath, formed by dissolving 24 parts of carbonate of soda and 6 lbs. of soap in 120 to 140 galls. of water, heated to 100° or 105° Fahr. (37°·7 to 40°·5 C.) After each passage of the goods over the roller, the activity of the bath is renewed by adding from $\frac{1}{2}$ to $\frac{5}{8}$ of a pound of soap to it.

(2.) Washed twice in clean water heated to the same point as the bath.

(3.) Transmitted three successive times through another solution the same as above, but without any soap: after each passage, except the last, $\frac{1}{2}$ to $\frac{5}{8}$ of a pound of soda is added to the liquor.

(4.) Exposed for twelve hours to the vapour of sulphur in the apparatus before alluded to, where 24 lbs. of sulphur are consumed for the decoloration of 40 pieces.

(5.) Passed three times over the rollers, as in the foregoing, in a bath in which 30 lbs. of soda crystals are dissolved in the same quantity of water as in (1.); this bath stands at 120° or 125° Fahr. (48·8 to 51°·6 C.), and after the first and second courses

of the cloth through the liquor, a little more than ½ lb. of crystals of the alkaline carbonate is added to it.

(6.) Again bleached in the sulphuring chamber, as in (4.).

(7.) Immersed in a bath in which soda crystals are dissolved, as in (5.).

(8.) Washed twice in water heated to 105° F.

(9.) Sulphured for twelve hours.

(10.) Washed twice in tepid, and once in cold water.

(11.) Tinged blue by passing the goods through a liquid impregnated with a mixture of indigo and carmine, or acetate of indigo, to suit the operator.

These, and similar methods of procedure, are usually adopted in the bleaching of woollen fabrics; but when there is a large amount of greasy and resinous impurities united with the filaments of the cloth, and it is intended for delicate colours, the scourings are not sufficiently effectual in freeing it from the last traces of those bodies which operate so injuriously in the dye-bath.

The following process is particularly adapted for goods intended for very delicate printing.

After ironing and washing with water, the raw fabrics are—

(1.) Passed twice through an alkaline soap bath, heated to 140° or 150° Fahr. (60° to 65°·5 C.), and composed of 44 lbs. of crystals of carbonate of soda and about 9 lbs. of soap in 120 or 140 galls. of water.

(2.) Rinsed in warm water.

(3.) Passed twice into a bath formed of 22 lbs. of soda crystals, and heated to the same degree as in (1.).

(4.) Rinsed in warm water.

(5.) Passed into the sulphuring apparatus for ten hours, using 22 lbs. of sulphur for each 250 pieces.

(6.) Rinsed in warm water.

(7.) Passed twice into a bath containing about 15 lbs. of soda crystals, and heated to 140° or 150° Fahr. (60° to 65°·5 C.).

(8.) Passed twice into a bath containing 12 lbs. of crystallized carbonate of soda, and heated as before.

(9.) Rinsed in warm water.

(10.) Passed into the sulphuring apparatus, using this time 15½ lbs. of sulphur.

(11.) Passed into tepid water.

(12.) Passed into a blue bath.

Bisulphite of soda solution is frequently used in bleaching fine qualities of wools, and to remove the yellow tinge imparted to the goods the usual blue bath is applied. J. B. Frézon, of Paris, treats the bleached goods, before putting them into the blue bath, with an aqueous solution of oxalic acid and salt, about 1 lb. of the acid and the same weight of common salt to 30 galls. of water. The fabrics are left about two hours in this solution, then washed and put into any of the usual blue liquors. This intermediate treatment is said to heighten the whiteness of the goods, and subsequently to facilitate the dyeing.

Alkaline cyanides have of late years been proposed for scouring wool; but whatever the merits of these agents may be, there is no doubt that the use of such poisonous substances is connected with too much risk ever to become general.

According to a French patent (Sanial & Beroujon, Lyons) woollen goods may effectively be scoured by steeping them in dilute solutions (about 2° B.) of alkaline sulphides.

Bleaching of Silk.—Silk is the produce of the caterpillar of the silk moth (*Bombyx mori*); the insect spins it round itself in the shape of a hollow ball, called a "cocoon," and remains there till it becomes a chrysalis. But the silk cultivator stops the development of the chrysalis by exposing the cocoons to the action of steam or heated air. The cocoons are then thrown into soft water, best into rain water heated nearly to boiling, and agitated briskly; they are next thrown into tepid water, where the operator takes hold of the end of the thread and attaches it to the bobbin of a reeling machine. The first portions, forming the outer part of the cocoon, are collected separately, and termed "waste silk;" the silk from the inner part of the cocoon constitutes the "raw silk."

The silk fibre is without cellular structure, thus totally differing from wool and the vegetable fibres; its colour varies from white to yellow. The chemical nature of silk has first been investigated by Roard (1807), later by Mulder, and recently by E. Cramer (1863). These researches show that silk consists essentially of two substances: the one constituting the fibre itself, is termed "fibroin;" the other is a varnish or gum covering the fibre. This latter dissolves in hot water, whilst the other is not affected by this agent.

According to Mulder, there are in—

	Yellow silk.	White silk
Substances soluble in water, ...	28·86	28·10
" " alcohol, ...	1·48	1·30
" " ether, ...	0·01	0·05
" " acetic acid, ...	16·30	16·50
Silk substance (fibroin), ...	53·35	54·05
	100·00	100·00

Cramer's analysis of the purified fibroin points to the formula $C_{30}H_{23}N_5O_{12}$; but formulæ of substances of this kind require to be received with great caution.

A characteristic property of the silk is the absorption of moisture to the extent of 30 per cent.; this moisture is not detected by the touch, and its correct determination is of importance to the buyer as also to the seller. There are special establishments on the Continent, mostly under government inspection, for the valuation of raw silk. The limits of this article do not allow the detailed description of the drying and weighing apparatus employed for that purpose.

Silk stuffs intended to be bleached have either already been partly bleached by the scouring operations which the silk has been made to undergo before weaving, or they are in the raw state. In the former case it is sufficient to immerse the goods for some time in running water; they are then boiled for an hour in a bath, consisting of about 2 ounces of soap

and 1 to 1¼ lbs. of bran for each piece of 8 to 10 yards long. The acid of the bran uniting with the excess of the alkali in the soap, prevents it from weakening the silk by dissolving it. On being taken from the bath, the goods are rinsed in water heated to 120° Fahr. (48°·8 C.), and then washed well with cold water in the dash-wheel.

In the second case, the goods, after being introduced into bags, are immersed in a boiler filled with water, holding about ½ lb. of soap to every 2¼ lbs. of dry silk. After having heated and kept the whole in ebullition for two or three hours, the stuff is withdrawn from the bath to rinse it in running water. When well scoured it receives a second soap bath similar to the preceding, and is again scoured by the dash-wheel. The scouring being finished, the silk is passed, during ten or fifteen minutes, into a solution holding about half an ounce of crystallized carbonate of soda for each piece of silk; from this the silk is taken, washed carefully, and then passed into water slightly acidified with sulphuric acid, and after remaining here for some little time it is taken out, washed in warm water, and finally in running water.

Silk fabrics thus bleached are pure enough for every kind of printing in which dark or deep colours are used, such as madder, prussian blue, cochineal, amaranth, and violet; and brown colours in general; but when it is desired to print lighter or more delicate colours, the goods should receive a slight sulphuring. In this case, liquid sulphurous acid is greatly preferable to the gas, and far more advantageous, since it may be employed in a very weak state. Care should be taken that the sulphurous acid be cautiously applied in whitening silk, as it always communicates a more or less yellow tinge, and even injures the thread or fabric after the colour has been abstracted by it.

According to Roard, raw silks, white or yellow, may be completely scoured in one hour, with 15 lbs. of water to 1 of the fibre, and a suitable proportion of soap. The soap and silk should be put into the bath half an hour before its ebullition, and the latter should be turned about frequently. Dull silks, in which the varnish has undergone some alteration, never acquire a fine white till they undergo the operation of sulphuring.

It appears that the Chinese use no soap, but a species of bean, wheat flour, common salt, and water. According to De Grubbens, the proportions used for the bath are 5 parts of beans, 5 of salt, 6 of flour, and 25 of water.

Claussen's process for cleaning silk is—

(1.) Boil it in a soap composed of butter and caustic potash or soda, for 2 or 3 hours.

(2.) Steep in a solution of carbonate of soda or ammonia.

(3.) Sour in a weak solution of sulphuric or muriatic acid.

For bleaching silk—

(1.) Steep in carbonate of soda or ammonia.

(2.) Steep in a solution of sulphurous acid in water, or expose it while wet to the fumes of sulphur.

An artificial shade is sometimes communicated to the silk by impregnating the bath with certain colours. These shades are distinguished by the term china white, azure white, silver white, thread white, &c., and are communicated by the addition of annato to the bath for china white, or by the addition of litmus or indigo in various proportions, as one or other of the shades is desired.

There are various other materials from which it is necessary to remove colouring matters. Such is the case with fatty bodies, oils, straw for artistic purposes, raw material for paper, &c. The methods of bleaching these will be found in the respective articles. We give here, however, that relating to straw.

In Tuscany, where straw for artistic purposes is prepared to a large amount, it is selected whilst the wheat is bearded and the grains are in a soft milky state. The corn is sown very thickly, so as to give a short thin straw. As soon as cut, the straw is spread out for three or four days, and as soon as the sap is dried up, it is tied in bundles and stacked for the purpose of expelling the moisture. Another exposure for some time in the meadows to the dew and atmosphere acts upon the colouring matter and promotes the bleaching. Before the decoloration is entirely effected, it is necessary to turn the straw several times, and to moisten it occasionally with water. When thoroughly exposed, the lower joints of the straw are cut off, and the parts chosen for use are acted upon by steam, which dissolves most of the remaining colouring matter, and then it is submitted to the vapour of sulphur to decompose the residue.

In this country the straw is prepared by acting upon the ordinary materials; first, with a boiling solution of caustic soda, by which a considerable portion of the organic matter and natural varnish is disintegrated; after this it is washed well to remove all the material which the alkali dissolves, and then exposed to the action of the vapour of sulphur, or to bleaching powder, in confined vessels. Care should be taken that the sulphuring does not produce any charring of the straw by its too rapid combustion, for this cannot be remedied when once it has taken effect. Three or four hours' exposure to sulphurous acid, and about the same time to the solution of bleaching powder, is sufficient to remove the stains remaining.

Kurrer states that the straw may be economically whitened by being steeped repeatedly in boiling water and very weak alkali, and after the whole of the soluble matters are in this way removed, treating alternately with very dilute solutions of oxychloride of calcium and sulphurous acid vapour till the decoloration has been effected. This method, though tedious, is said to be very effectual for divesting the straw of its natural varnish, which renders it brittle.

BONE.—*Os*, French; *Knochen*, German; *Os*, Latin. —The various parts of the skeleton, or the solid framework supporting and protecting the softer portions of the body of animals of the superior orders, are termed bones. They are invested with a thin membrane called the *periosteum*, which is traversed by the nerves and bloodvessels, and has beneath it a still thinner membrane. These together

compose a thick tissue which is convertible into jelly by boiling with water, affording glue, &c.

Bones are not equally solid throughout, but present to view on the surface an osseous mass of a more compact nature, while the interior appears as a cavity divided into minute cellules by bony partitions. The cartilaginous portion is formed before the deposition of the earthy substance occurs, and the ossification always proceeds from certain fixed points. Bony tissue consists of bone-cartilage, or *ossein*, and tribasic phosphate of calcium, Ca_3PO_4, together with phosphate of magnesium, Mg_3PO_4, carbonate of calcium, and fluoride of calcium.

The organic part of the bones may be obtained in a separate state by immersing them in dilute hydrochloric acid. The lime salts are dissolved by the acid, and a kind of skeleton remains in the form of a cartilaginous substance, transparent, flexible, and elastic, exactly retaining the form of the bones; this, when dried, resembles horn. By boiling in water it is totally converted into gelatin, with the exception of a few fibres, derived from the fine blood-vessels, which are insoluble, and may be separated by filtration.

The chief difference between bone cartilage and gelatin is that the latter dissolves very rapidly in hot water, whilst the bone-cartilage is insoluble until it has been by long boiling converted into gelatin. The chemical constitution of the two are almost identical.

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	
Isinglass,.......	50·76	6·64	18·32	24·69	MULDER.
Bone-cartilage,..	50·13	7·07	18·45	24·35	VON BIBRA.

Bone ash—the earthy salts of bones—is best obtained by calcining the bones; but there are substances then present which did not antecedently exist in them—as, for example, sulphate of soda, formed from sulphur in the cartilage—there are also some alkaline carbonates derived from the same source. The carbonate of lime of the bone loses most of its acid at a white heat.

BONE GLUE—*Patent Glue.*—The manufacture of glue from bones is thus described by WAGNER.

Boiling out the Grease.—The bones are put into water and boiled in a cauldron, the fat floating to the surface. Frequently, in order to save fuel, the bones are put into an iron-wire basket, which is removed after the boiling has continued for some time, the bones thrown out and fresh ones put in, the boiling being continued until a thick gelatinous liquor is obtained. The fat or grease is removed from the surface by means of ladles. The gelatinous mass obtained by this process is either used as a manure or given to cattle. In some works bones have been exhausted with bisulphide of carbon for the purpose of extracting the grease.

Treating the Bones with Hydrochloric Acid.—The bones having been drained are placed in baskets, and with these are immersed in tanks to more than half their height, the tanks being filled with hydrochloric acid at 7° B.(= 1·05 spec. grav. = 10·6 per cent. of hydrochloric acid). Ten kilogrammes of bones (22 lbs.) require 40 litres (8·8 gallons) of acid. The bones are kept in this liquor until they become quite soft and transparent. They are next drained, and then with the baskets immersed in a stream or brook, with a good supply of running water to wash out the greater portion of the acid, which is fully neutralized by placing the bones in lime water, again followed by washing with fresh water. The bones are then ready for boiling.

Dr. GERLAND has suggested the use of sulphurous acid instead of hydrochloric acid.

Conversion of the Bone Cartilage into Glue.—The cartilaginous substance having been either partly or completely dried, is put into a cylindrical vessel containing a perforated false bottom, and between that and the real bottom a tube. To the top of the vessel a lid is fitted, provided with an opening for a steam-pipe leading from a small boiler. Shortly after the admission of the high-pressure steam a concentrated glue solution begins to run off from the pipe at the bottom of the cylinder; this solution is usually so concentrated as to admit of being at once run into moulds, and when solidified the jelly is cut into cakes of the size and shape met with in the trade.

The moulds into which the glue solution is poured (through a strainer made of metal gauze) are of wood, and generally a little wider at the top than at the bottom, so as to admit of an easy removal of the solid material. At the bottom of the moulds a series of grooves are cut at such a distance from each other as agrees with the size of the intended glue cake. Before the liquid is poured into the moulds they are thoroughly washed, and either allowed to remain damp, or if dried, are oiled so as to prevent the solidifying gelatin from adhering to the wood. Recently moulds made of zinc and sheet iron have been introduced.

The moulds are filled with lukewarm glue solution, and when the glue is sufficiently hard, it is gently loosened from the sides with a sharp tool, and the mould having been turned over on a wooden or a stone table, previously damped, is lifted off the block of gelatin, which is next cut into cakes or slabs. The cutting tool is simply a piano-wire, or more frequently a series of these stretched in a frame, at a sufficient distance from each other to make the cakes of the desired thickness, the frame being placed on small wheels so as to be easily moved.

Drying.—This operation is performed by placing the gelatin cakes on nets made of twine, stretched in frames, and exposed in a dry airy place to the action of the sun. The drying is the most difficult operation of the glue-making process, because the temperature of the air and its hygrometric condition exert a great influence on the product, especially during the first few days. The glue will not bear a temperature above 68° Fahr. (20° C.), because at a higher temperature it becomes again fluid, and as a matter of course flows through the meshes of the net, and adheres to the twine so strongly as to require the nets to be put into hot water for the removal of the mass. Too dry air causes an irregu-

larity in the drying of the glue, and as a consequence the cakes become bent and cracked; while frost causes disintegration so as to necessitate remelting of the glue; hence it follows that drying in the open air can only be effected in the spring and autumn.

The glue boilers have tried to dry glue by artificial heat, but this plan has not been much adopted, owing to the fact that a slight excess of heat causes a re-melting of the gelatine, and this the more readily if ventilation is at all neglected.

Drying rooms, as recently constructed, are large sized sheds, fitted with the required frame-work for receiving the gelatine cakes, and heated by steam pipes placed on the floor near the latter. The walls are provided with openings which can be closed by means of valves, while there are ventilators in the roof arranged to obtain a proper circulation of air. As the glue placed nearest to the floor becomes soonest dry, it is, with the frames upon which it is placed, removed after eighteen to twenty-four hours to a higher part of the drying room, which is not heated at all if the outer air has a temperature of 60° to 68° Fahr. (15°·5 to 20° C.). The drying shed, or room, is by preference built so as to face the north.

When the glue has been thus dried as much as possible, it is generally quickly dried in a stove in order to impart hardness. It is next polished by being immersed in hot water, then cleaned with a brush, and again dried.

BONE BLACK—Animal Charcoal.—*Noir d'os*, French; *Knochenschwartz*, German.

Properties.—Bone black possesses the property of abstracting many solid substances from solution, and of completely absorbing the colour of very many vegetable and animal solutions, and of rendering quite limpid and colourless the water charged with it. Vegetable charcoal shares this property with it in a certain degree, but does not possess the same energy. Animal charcoal differs very materially in appearance and in physical and chemical properties from vegetable charcoal. The former in a newly manufactured state obstinately refuses to part with the whole of its nitrogen, and this can only be got rid of by repeated washings with hot water and reburnings.

The first observations on this subject were made by Löwitz at the close of the last century. He observed with care the decolouring properties of vegetable charcoal, and endeavoured to make some applications of it. From 1800 to 1811 it was extensively used for depriving crude syrups of colour; but at the latter date M. Figuier, an apothecary of Montpellier, showed that the same effect was produced by animal charcoal, not only in a better manner, but also more speedily and certainly. The discovery was promptly applied to the refining of sugar, and now forms one of the most essential processes of that art.

In using animal charcoal for depriving a liquid of its colour, the operation is more successful when the latter is slightly acid or neutral, than when it is alkaline.

The action of animal charcoal on coloured liquids is usually accelerated by heat. In most cases the liquor to be deprived of colour is brought to a state of ebullition, the charcoal is thrown in, the mixture agitated for some moments, and then filtered.

Animal charcoal is almost always prepared from the bones of the ox and the sheep, horse bones are seldom used as they produce an inferior charcoal. It contains, therefore, the salts of lime, which enter into the composition of these bones; and consists of about 10 per cent. of nitrogenized charcoal, 2 of carbide or silicide of iron, and 88 of phosphate or carbonate of lime, mixed with a little sulphide of calcium, or of iron.

The animal charcoal of commerce is subject to very great variations in quality, due to various conditions of the raw material and bad manufacture. When either over or under calcined, it is less energetic; in the former case, because it is less porous; in the latter, because the animal matter, not being quite consumed, makes a kind of varnish in the charcoal which prevents its acting. The best of all is that which has been calcined to the exact point of destroying the animal matter, but no further.

The state of porosity of the charcoal is important. Thus the charcoal obtained by calcining a mixture of potassa and animal matter in the manufacture of prussian blue, and which remains after the lixiviation of the residues, possesses the decolouring property to a degree which ordinary bone-charcoal never attains. This charcoal is pure; the decolouring power of this charcoal is ten times more energetic than that of crude bone black.

The following table of the decolouring power of different varieties of charcoal is by Bussy:—

Species of charcoal.	Weight.	Indigo test consumed	Molasses test consumed.	Blanching by indigo.	Power by molasses.
	gramme.	litres.			
Blood calcined with potassa,	1	1·60	0·18	50	20
Blood calcined with chalk,	1	0·57	0·10	18	11
Blood calcined with phosphate of lime,	1	0·38	0·09	12	10
Gelatin calcined with potassa,	1	1·15	0·14	36	15·5
Albumen calcined with potassa,	1	1·08	0·14	34	15·5
Starch calcined with potassa,	1	0·34	0·08	10·6	8·8
Charcoal from acetate of potassa,	1	0·18	0·04	5·6	4·4
Charcoal from carbonate of soda by phosphorus,	1	0·38	0·08	12	8·8
Calcined lamp-black,	1	0·128	0·03	4	3·3
Lamp-black calcined with potassa,	1	0·55	0·09	15·2	10·6
Bone black treated with hydrochloric acid and potassa,	1	1·45	0·18	45	20
Bone black treated with hydrochloric acid,	1	0·06	0·015	1·87	1·6
Oil calcined with phosphate of lime,	1	0·064	0·017	2	1·9
Crude bone black,	1	0·032	0·009	1	1

In fact, the charcoal proceeding from pure organic matter has little decolouring power. That which is mixed, on the contrary, with abundance of earthy matter, decolours tolerably well, and that which has been formed in the midst of fusible saline substances still better. Charcoal of the second and third classes is always of a dull colour, which implies that it exists in a very minute state of division. BUSSY and PAYEN have shown that they took from some, and imparted to others, the decolouring property, according as they rendered them lustrous or dull, by suitable modifications in the process of carbonization.

The first and most striking fact seen on referring to the table is, that the relative decolouring powers as measured by indigo or molasses are far from being identical. The author of the table remarks on this subject, that the more charcoal a substance requires for its decolouration, the more does the decolouring power of the perfect charcoal tend to diminish, as compared with the ordinary bone-charcoal taken for the unit measure of this energy, in all cases.

A result not less evident is, that the blanching power is inherent in the pure carbon, since that which is obtained from the decomposition of carbonate of soda possesses it in a high degree. Moreover, although the facts relative to the decolouring power of animal charcoal have been here brought together, this property must be considered as common to every kind of charcoal, provided it exist in a minute state of division.

In recapitulation, it will be seen from what has just been stated, firstly, that the decolouring property is due to the charcoal; secondly, that it is modified, nevertheless, by the presence of earthy salts; thirdly, that the charcoal acts by combining with the colouring matter; fourthly, that this combination is effected according to the fine division of the particles of the charcoal; fifthly, that this state may be communicated to it by a suitable mixture of mineral matters, particularly of potassa, during carbonization, provided they are supplied in sufficient quantity to prevent the charcoal from agglomerating.

It was formerly the general opinion that the action of animal charcoal was only exerted upon bodies of organic origin, particularly colouring principles, bitter and aromatic substances, as turmeric, litmus, indigo, sugar, syrups, &c.

GRAHAM has, however, found that inorganic matters were equally influenced, and it has been proved that charcoal abstracts the lime from lime-water, and completely absorbs the metallic oxides, particulary those of lead, as also ammonia and potassa, from their aqueous solutions. According to experiments conducted by CHEVALLIER, neutral acetate and nitrate of lead are entirely taken up by bone charcoal, whether it is in a washed or unwashed state. The former is more readily absorbed than the latter. The absorption requires—with from one to ten parts of charcoal to one of the salt—from one or two to six days at the ordinary temperature, but at a boiling heat from two to five minutes only.

GRAHAM, by bone charcoal, even separated the iodine from iodide of potassium. The investigation of WEPPEN appears to prove that the action of the charcoal extends to all metallic salts; with the following no doubt remains of this being the case, viz.: the sulphates of copper, zinc, chromium, and protoxide of iron, nitrates of nickel, silver, cobalt, sub-oxide, and oxide of mercury, acetate of lead, tartrate of antimony, and potassa, protochloride of tin, protochloride of mercury, and acetate of the sesquioxide of iron. In the separation of these salts by charcoal, one of three cases may occur: the salt is absorbed unchanged: or a basic compound is precipitated upon the charcoal: or the oxide in the salt is reduced to the metallic state. Some metallic acids, as antimonic and tungstic, are thrown down from their potassium or ammonium salts, although no effect is produced on arsenite or arseniate of sodium. The salts of the alkaline metals are little affected. Free acids either hinder or entirely prevent the precipitation of the metallic oxides.

PREPARATION.—The first step in the preparation of animal charcoal is to take what are technically termed "raw bones," which possess a certain amount of grease, this together with some gelatine is removed by boiling. The grease is used in the manufacture of candles and soap; the gelatine, when concentrated, is employed in sizing cloths, yarns, &c. The bones after being boiled are subjected to the influence of a red heat for some hours.

The calcination of bones to produce animal charcoal is conducted in different ways; by one method the bones are calcined in small pots closely packed up in a kiln. On this plan the bones, broken into small fragments, are placed in small cast-iron vessels of the form shown in Fig. 1, about three-eighths of

Fig. 1.

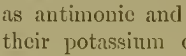


Fig. 2.

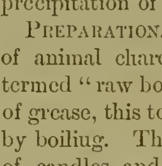


Fig. 3.

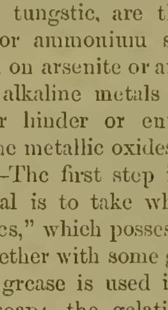
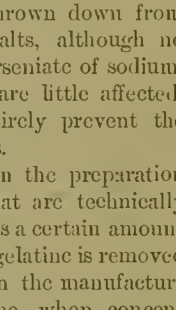


Fig. 4.



an inch in thickness, two of which, after filling, are dexterously placed with their mouths in contact, and then luted together with loam. The lip of the upper is made to fit inside that of the lower one. These double vessels, a pair of which contain about 50 lbs. of bones, are arranged in parallel rows, and also upon each other, in an oven, till it is filled. This oven or kiln may be either oblong or upright. The latter is represented by Figs. 2, 3, and 4. A is the fireplace, or grate for the fuel; C C are apertures in the dome of the furnace for the admission of flame; the divisions of these orifices are shown in Fig. 2; B is the wall of brickwork; D is the space where the

pots are placed; E is the door by which the workmen carry in the vessels, and which, before the carbonization commences, is built up with firebricks and plastered over with loam; F F are flues for carrying off the disengaged gases into the chimney, G.

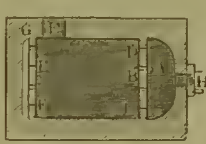
Fig. 5 is a longitudinal section and Fig. 6 a ground plan of a horizontal kiln for calcining bones. A is the fire-chamber, on a level with the sole of the oven; it is separated from the calcining hearth, C, by a pillar, B. In this pillar or wall several rows of holes, D, are left at different elevations; E is the entrance door; F F are the outlet vents for the vapour, smoke, and gases into the chimney, G; a sliding damper plate, for regulating the admission of air into the fire in the space, A, is denoted by H.

The offensive emanations are, by this arrangement, partly consumed and partly carried off with the smoke. For the complete destruction of the smell the vapours, &c., should pass through a small furnace, or be otherwise submitted to combustion.

In both the kilns represented the interior walls are built of firebricks. In the oblong one the heat is greatest near the vaulted roof; in the upright one, near the sole; the pots containing the larger lumps of bones should be placed accordingly. The former oven is generally constructed to contain from 100 to 150, and the latter about 70 pots; the dimensions may, however, be varied at pleasure.

Fig. 5.

Fig. 6.



After the pots have been properly packed into the oven, and the entrance door is closed, the fire is at first kept low, but is afterwards raised and a brisk heat maintained for eight or ten hours. The draught is then moderated by the door of the ash-pit, and the damper being nearly closed, a steady ignition is kept up for an additional six or eight hours without fresh firing, after which time the doors are opened to cool the furnace. After this has been effected the brickwork which closed the entrance is taken down and the kiln is emptied, but is immediately filled again with a fresh set of vessels previously prepared. The pots just withdrawn are, after a short period, opened, and the contents put into the magazine.

When the preparation of bone black is connected with that of ammoniacal salts, the carbonization is performed in cylinders of cast iron, terminated at one extremity by a pipe of 3 inches diameter, which conducts the evolved gases into a long series of refrigerating apparatus. The other end is opened or closed at will by means of a movable disc of the same metal. These cylinders are placed horizontally in a furnace. They are filled with crushed bones, previously deprived of their fatty matter, and the disc being closed and luted, the temperature is raised to a red heat and maintained at that point for thirty-six hours; at the end of which time the lid is opened, the residue withdrawn, and inclosed in metal receivers or boxes, to be extinguished while the cylinders are recharged.

Bone black thus prepared requires reducing to a finer state of division. For this purpose it is first crushed to a coarse powder, and the process is concluded by passing it between stones, similar to those used for grinding corn, but it may be pulverized between steel cylinders, and in many other ways. It is generally damped during grinding to lay the dust which would otherwise rise.

The ammoniacal liquid produced in distillation of the bones is saturated with sulphuric acid, and evaporated to form sulphate of ammonia.

If it is not desirable to collect the other products of the distillation of the bones, the pipe which allows their escape may be immediately carried under the firegrate, where combustion will ensue, thus not only avoiding their disagreeable odour, but also economizing fuel.

Bone black is sometimes employed as a pigment; and as in this case it requires to be more thoroughly divided, it is made into a liquid paste with water, which is put into *a colour-mill*, and ground for the necessary time; the resulting mass is then put into earthen moulds, and left to dry.

Bone-black forms the base of blacking; it is also used by some sugar refiners in the early stages of refining. The animal charcoal dust unsuitable for sugar refining purposes is converted by sulphuric acid into superphosphate of lime. Animal charcoal is the only form of charcoal now used by British refiners, and the quantity of bones annually used in its manufacture in this country is over 25,000 tons. The largest manufacturers in the world are G. LOCKYER & SONS of London and Bristol; the oldest houses in the trade are those of G. TORR, London, and EDEN, JONES, & Co. of Bristol; the latter is now merged into that of G. LOCKYER & SONS.

Ivory-black is obtained by analogous processes. It forms a beautiful velvety black, which is used in making the best printing inks.

REVIVIFICATION.—On the Continent, the renovation of the charcoal, with some slight modifications in the methods of carrying it out, consists in submitting it to fermentation; washing (in some cases with hydrochloric acid, and afterwards with water; in others, with water only); drying; and finally heating to redness.

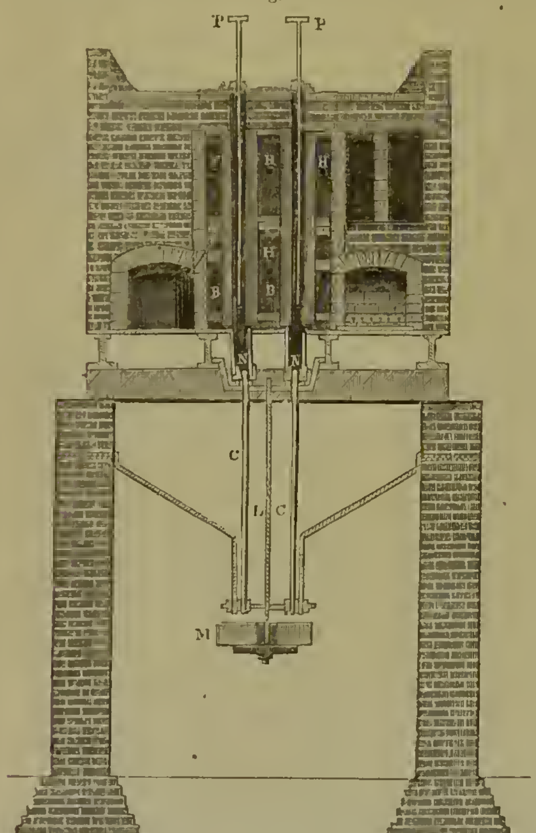
During this second burning the temperature is much lower than that originally required; consequently, the operation is effected without pots, and the danger of burning the charcoal to ash is proportionally diminished. In France the process is conducted in reverberatory furnaces, having a flat-arched roof, and the doors made very close. In Magdeburg, narrow cylinders, fitted at the top with a lid, and below with a sliding door, are used, several of the retorts being at the same time placed upright in a reverberatory furnace.

The fermentation of the charcoal previous to burning is advantageous, as the greater portion of the

absorbed organic matters is decomposed and evolved as gas, leaving only a small quantity in the pores to be charred. On the other hand, however, it converts any lime which may have been taken up into carbonate, and renders its removal more difficult.

One of the best methods is that proposed by SCHATTEN, and carried out at Magdeburg. As the charcoal leaves the filters, and before the lime has had opportunity for absorbing carbonic acid, it is completely saturated with dilute hydrochloric acid, which immediately acts very energetically, and causes evolution of much heat. The charcoal is then placed in large reservoirs, and water, mixed with about one-half per cent. of hydrochloric acid, poured upon it. This treatment occasions a lively fermentation, which

Fig. 7.



extends over about eight days, when the water is removed, and another quantity of fresh supplied. After this has been repeated several times, the charcoal is treated with water, again containing acid, in smaller vessels, until the lime is completely saturated, when it is again washed, and then heated to redness. Any excess of acid must be carefully avoided, as it would attack the phosphate of lime, soften the charcoal, and render it useless. The upper layers of bone-black in the filters which first come into contact with the saccharine juice, hold six times as much lime as those below.

Fig 7 is a sketch of PARKER's charcoal re-burner, patented some years ago.

Narrow spaces constructed of firebrick, the bottoms of which are indicated in the engraving at N, are surrounded by the flames from a fire passing up the flues, B, F, and H, which retain them at a low red heat. These narrow upright brick retorts are connected below, so as to be air-tight, with the still narrower sheet-iron receivers or coolers, C C, into which a certain quantity of the re-burnt charcoal can be allowed to fall at short intervals, and cool without access of air. It is ultimately removed underneath, passing through the measurer, M. The re-burners are open at the top, where the charcoal is admitted and piled up in a heap above the aperture, so that, as one portion is removed below, its place is immediately occupied by a quantity falling down from above. P P are tubes through which the temperature in the interior of the charcoal can be observed, and which also serve as an exit for the gases evolved in the lower part of the re-burners.

Figs. 8, 9, and 10 represent the apparatus of PONTIFEX and WOOD—the first being a plan, the second a longitudinal, and the third a transverse section.

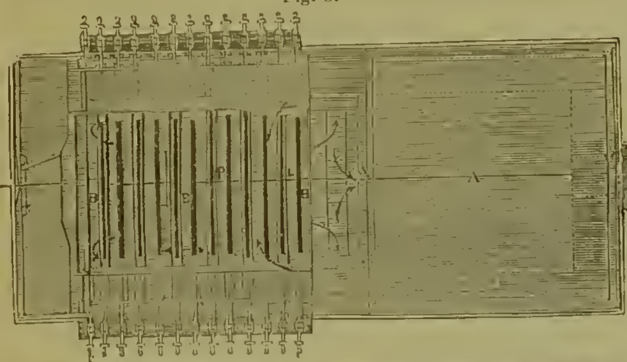
The charcoal that has been used in the filters, after having been washed in a cistern, is taken out and laid aside to allow the water to drain from it; it should then be removed to the re-burner, and placed on the wrought-iron plate, A, which forms the back part of the top; the fire having been lighted, the plate will become hot, and thoroughly dry the charcoal before the retorts, B B B, B B B, are heated. When it has become perfectly free from moisture, it should be raked forward into the retorts, filling them up, and heaping the charcoal over them to the height of 6 inches or more. After the retorts are thus charged, a red heat is applied for fifteen or twenty minutes, after which the operation is finished.

The slides, *a a*, in the boxes, C C—Fig. 10—are then opened, which allows the charcoal contained in the pipes, D, and a portion of that in the retorts, to run into C C; the slides are subsequently closed, the charcoal descends, and the hollows produced in the heap over the retorts are supplied from the charcoal on the plate, A. The slides, E E, at the bottom of the boxes are now opened, and the charcoal having become tolerably cool is run into trucks or boxes placed below C C, when, after a little water has been thrown on it to reduce the temperature still further, it may be stowed away, ready for use. The first charge is never properly burned, a portion having been left in the pipes, D D, which are below the heat of the fire; this must, therefore, be again thrown on the top of the retorts. After the apparatus is once at work, a charge may be drawn every fifteen or twenty minutes, according to the temperature, which may be regulated by the damper, F.

The fire in this arrangement should never be put out, as the cooling of the retorts soon destroys them. They may be worked at any velocity, by allowing a greater or less draught, but the charcoal must never be permitted to become red-hot above the tops of the retorts, where it is in contact with the air. If the charcoal is properly heaped up over the retorts, and the charge drawn regularly, the apparatus works admirably.

The receptacle, C, into which the charcoal is let down when it is sufficiently burnt, is divided into as many compartments as there are retorts, each holding half the quantity burnt in one of them, the corresponding receptacles on the other side of the apparatus having the remainder. The valves, *a a*, are flat plates of cast iron working in grooves, and are intended to open or close the communication between the

Fig. 8.



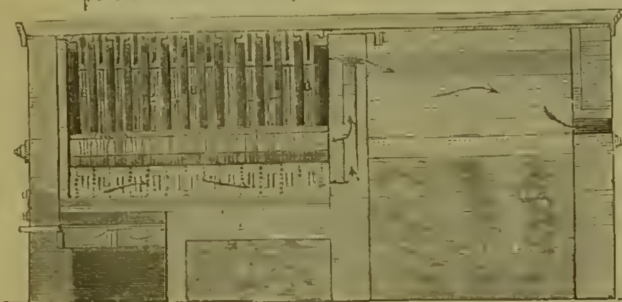
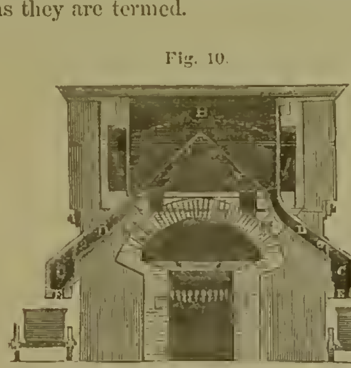


Fig. 9.

retorts and the receptacles. They are worked by the handles abutting on each side of the plan.

In the longitudinal section of the re-burner, a section is shown of the whole of the retorts cut across in the middle, on the line of the union of the two legs; and consequently it shows the end-sides of the retorts slanting towards these legs, or "breechings," as they are termed.

Fig. 10.



The transverse section shows the retorts cut across the middle at right angles to the longitudinal section.

The direction of the flues is shown by the arrows on the drawings. Each retort revivifies 50 lbs. of charcoal every fifteen or twenty minutes, and, conquently, the burner revivifies about 9½ cwts., at least, of spent charcoal per hour.

Some substitutes have been proposed for bone charcoal; none of them, however, are of equal power. The best hitherto known is that obtained from bituminous shale. This mineral is constituted, like bone, of an earthy and an organic constituent, and yields a similar charcoal. Another imperfect substitute is obtained by charring molasses.

BORACIC ACID.—Boric acid.—*Acide boracique, acide borique*, French; *acidum boracis*, Latin; *sal sedativum, Hombergii, sal narcoticum vitrioli.* This acid was first obtained by Homberg in 1702.

It is prepared in the pure state by dissolving 40 parts of sodium biborate (borax) ($2NaBO_2,B_2O_3, 10H_2O$) in 100 parts of boiling water, and adding 25 parts of hydrochloric acid to the hot solution. The boric acid deposits as the liquor cools; it is then collected on a filter, washed with cold water, drained, redissolved in a little hot water, and recrystallized, the crystals washed with cold water and pressed between folds of bibulous paper. The mother liquor and the washings on evaporation afford a further quantity of the acid. The boric acid, when dry, still retains a trace of free hydrochloric acid, which may be driven off with a part of the water of crystallization by heating to a temperature of abont 234° Fahr. (111°·1 C.). The usual method consists in decomposing borax with sulphuric acid; but the boracic acid thus obtained is always contaminated with a certain portion of the sulphuric acid, which is dissipated only with great difficulty.

The crystallized hydrate of boric oxide, *i.e.*, boric acid, is soluble in 25·7 parts of water at 64°·4 Fahr. (18° C.), in 14·9 parts at 77° Fahr. (25° C.), in 10°·7 parts at 122° Fahr. (50° C.), in 4·7 parts at 167° Fahr. (75° C.), and in 2·97 parts at 212° Fahr. (100° C.). Its solubility is much increased by the presence of tartaric acid or tartrates. From the boiling solution it deposits as it cools in pearly six-sided scales, having the specific gravity 1·48. Boric acid dissolves in alcohol, to the flame of which it communicates a beautiful green colour. It also dissolves in several of the mineral acids, especially sulphuric. It has little taste, and colours litmus deep red in the cold, but scarlet when hot; it renders turmeric brown, like an alkali. The glacial acid, when exposed to the atmosphere, absorbs water, intumesces, and becomes opaque; it is readily fusible, and forms combinations with many of the metallic oxides having the same property. At a white heat boric acid slowly sublimes when exposed to the air. When perfectly pure, and slowly deposited from its aqueous solution, it forms small, white, translucent, prismatic crystals.

Heated to 212° Fahr. (100° C.) boric acid parts with 21·8 per cent. of its water; heated for some time at 320° Fahr. (160° C.) it is deprived of more water and becomes $H_2B_4O_7$. At a red heat the

whole of the water is volatilized, leaving boric oxide (B_2O_3).

The green colour communicated to the flame of alcohol is so peculiar that it is used as an indication of the presence of this acid. If a salt, free from copper, for example, be suspected to contain boracic acid, a little sulphuric acid is added, and the mixture dried by a gentle heat; this will separate the boracic acid and dispel any chlorine or hydrochloric acid that may be present, which also gives a greenish-blue flame. On adding alcohol to the dry mass and igniting; if the smallest quantity of this acid be present the green tint will sooner or later appear, especially if the mixture be stirred rapidly with a glass rod.

When boracic acid is perfectly dry it is fixed; but during the ebullition of its aqueous solution it is carried off by the vapour in large quantity. On being distilled with alcohol a still larger portion of the acid is carried off in the spirituous vapour than is the case with the steam.

By the action of boric acid on metallic oxides or their salts, borates are formed. Boric acid is, however, so feeble in its affinities at ordinary temperatures that its salts are completely decomposed by nearly all acids, including carbonic acid and sulphuric acid, and are in dilute solution even split up by water.

When concentrated, on the other hand, boric acid decomposes carbonates and soluble sulphides, and as before remarked, its anhydride at fusing temperatures sets free all volatile acids from their metallic combinations.

The preparation of boric acid, on the large scale, has been well described by PAYEN, *Précis de Chimie Industrielle*. The works in Tuscany are situated on a gently sloping ground, constantly disintegrated by currents of gas and of vapours, which project liquid columns in the middle of small basins of water, and afterwards rise into the air in whitish clouds. At the bottom of these hills are situated the manufactories, at a short distance from each other. They are named Larderello, Monte-Cerboli, San Frederigo, Castel-Nuovo, Sasso, Monte-Rotundo, Lustignano, Serazzano, and Lago. In these establishments, although an enormous mechanical force is incessantly manifested, and an evaporation effected exceeding 7875 tons of water annually, and producing about 738 tons of crystallized acid; neither machines, nor crude substances, nor combustibles, are perceptible. The *soffioni*—numerous jets of vapour—do the whole of the work; it is merely requisite to give their powerful blast a proper direction, to obtain both the crude solution and the heat required for its concentration.

The lagoons of Tuscany are spread over a surface of 30 miles. As they are approached, the earth seems to pour out boiling water as if from volcanoes of various sizes. The soil varies, but is principally chalk and sand. The heat in the immediate vicinity is intolerable, and the vapour impregnates the atmosphere with a strong and somewhat sulphurous smell. The whole scene is one of terrible violence and confusion—the noisy outbreak of the boiling stream—the rugged and agitated surface—the volumes of steam—the impregnated atmosphere—the rush of waters among bleak and solitary mountains.

The ground, which burns and shakes beneath the feet, is covered with beautiful crystallizations of sulphur, &c. Formerly the place was regarded by the rustics as the entrance of hell, a superstition derived no doubt from ancient times, for the principal of the lagoons and the neighbouring volcano still bear the name of Monte Cerboli—*Mons Cerberi*. The peasantry never pass the spot without counting their beads.

The lagoons have been brought into their present profitable action within a very few years. Scattered over an extensive district, they have become the property of Count LARDEREL, to whose energy and intelligent skill the great increase in the production of boracic acid of late years is due.

Many difficulties have impeded this manufacture; but Count LARDEREL has succeeded in overcoming the most serious by substituting, instead of the expensive wood fuel, a most happy application of the superabundant vapour which everywhere escapes from the soil, and by which a saving of nearly £500,000 has been effected. PAYEN, in his researches into the nature of the gases, and of the substances which they carry with them into the lagoons (small muddy lakes), found the non-condensed gases to consist of—

	Centesimally.
Carbonic acid,	57·30
Nitrogen,	34·81
Oxygen,	6·57
Sulphide of hydrogen,	1·32
	100·00

The condensable products, and the substances conveyed by the currents of vapour, vary: generally they comprise water, clay, sulphates of lime, of ammonia, of alumina, and of iron, hydrochloric acid, organic substances, and lastly, little or no boracic acid; they deposit sulphur in all the narrow fissures and pores which they traverse. The temperature of these vapours was found to vary from 206° to 212° Fahr. (96°·6° to 100° C.).

It has been found impossible to obtain this acid by condensing the vapours of the soffioni, even in very large and long tubes; to obtain it, it is requisite that their apertures should be directly covered by the liquid of the basins. It is frequently observed that a portion of the water absorbed, when these lagoons are filled, is subsequently thrown out with the vapour. And though the cause of the currents of gas, and of the elevation of the temperature, appears to have remained constant for many years, the production, or at least the arrival of the boracic acid at the surface of the soil, seems to depend on the introduction of water into the fissures.

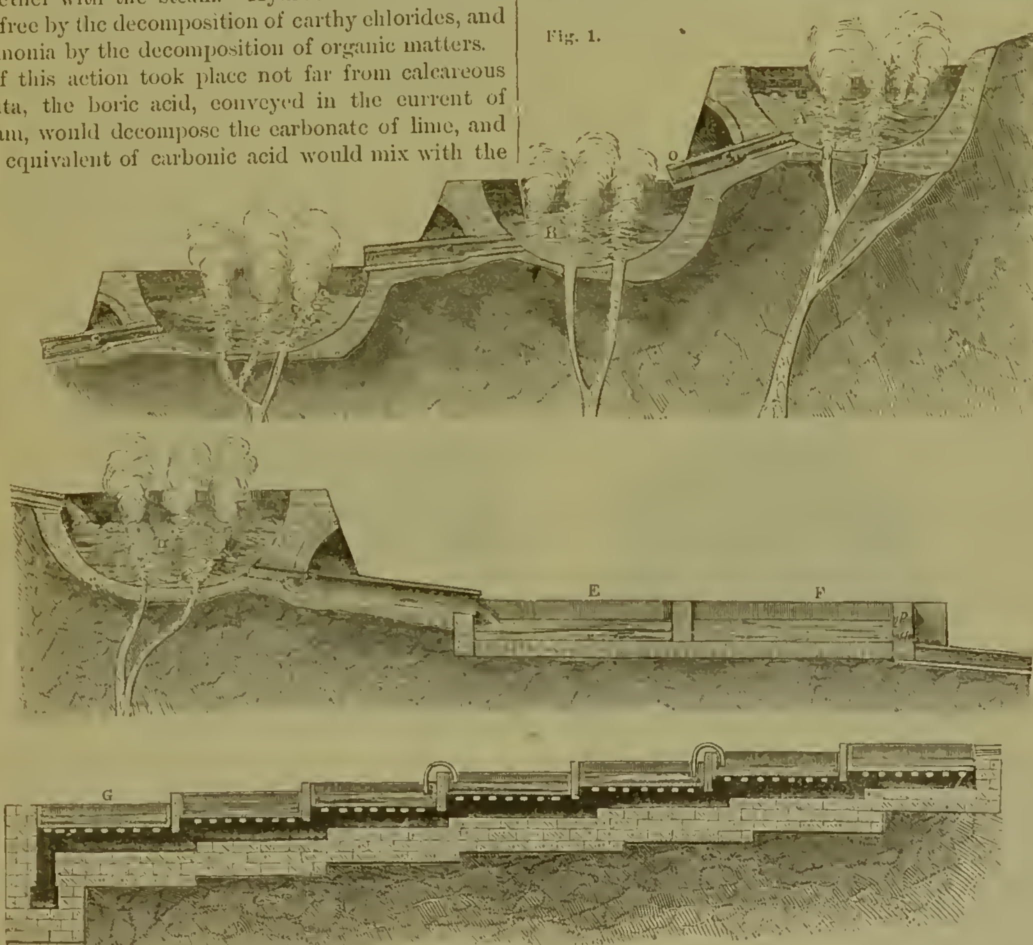
Suppose the water of the sea, percolating through some fissure to a great depth, had its temperature raised to a high degree, and that it found in the soffioni an issue for the steam produced, the vapour, mixed with the projected water in passing over the

deposits of boric acid, would carry this with it, and by the reaction of the organic matter contained in it on the sulphates, would produce sulphides, from which boric acid would expel sulphide of hydrogen.

DUMAS has suggested that a deposit of sulphide of boron, situated at a great depth, is percolated by sea-water; a considerable action takes place, from which results boric acid and sulphuretted hydrogen at a high temperature, these products being evolved together with the steam. Hydrochloric acid is also set free by the decomposition of earthy chlorides, and ammonia by the decomposition of organic matters.

If this action took place not far from calcareous strata, the boric acid, conveyed in the current of steam, would decompose the carbonate of lime, and the equivalent of carbonic acid would mix with the other gases. At a certain distance the sublimed boric acid might form deposits, and, according as the water of the lagoons descended to this point or not, the current would again carry up with it boracic acid, or pass without volatilizing it. The air furnished by the sea-water would enter the fissures, and in the presence of sulphuretted hydrogen would determine the formation of sulphuric acid. This, in its turn, would produce sulphates of calcium, of ammonium, of aluminium, and of iron, taking the

Fig. 1.



lime from the calcareous mass, the ammonia from the vapours, and the alumina and iron from the clay.

These different salts are formed, or dissolve in the waters near the surface of the soil, and explain its disintegration. The appearance of sulphur, and the presence of a little oxygen, which accompany the various substances contained in the soffioni and in the troubled waters of the lagoons, results from the accidental introduction of air.

The methods adopted in the nine manufactories are, with some slight modifications, identical: they consist in the construction of rude circular basins (Fig. 1) around each of the centres of irruption, where two or more of the largest fissures terminate; and further, in conveying into the highest of these basins or lagoons, A, the water of some neighbouring spring. After remaining in the basins for twenty-four hours, during which time the water has been constantly agitated by the subterraneous jets, the plug, O, is opened, and the liquid passes by a small canal, *m n*, into the lower lagoon, B, where it is confined for the same length of time, and becomes charged with more boric acid. The solution is successively passed into the lagoons, C, D, the liquid, as it is drawn off from an inferior basin, being constantly replaced by that contained in the one above.

All experiments made with a view of obtaining the boric acid directly by condensing the vapours in towers or chambers, have been fruitless.

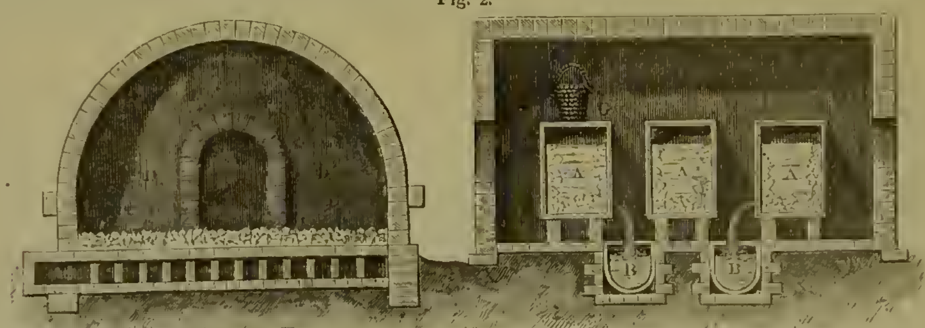
When the solution has arrived at the last lagoon, D, and is sufficiently saturated, it is transferred into a reservoir, or cistern, E, 20 feet square and a little more than 2 feet deep, where the greater portion of

the sediment is deposited. The supernatant liquid is decanted either into a second reservoir, F, or into two batteries, each of seven leaden evaporating pans, G G, 10 feet in breadth and 14 inches in depth, supported by strong wooden rafters above the masonry, on an inclined plane, which allows the vapour from some soffioni inclosed in pipes, and which enters at H, to ascend freely beneath the pans, which are arranged on different levels, to the upper portion, where the excess is given off outside the factory. The solution of the boracic acid in the reservoirs has usually a very low specific gravity. The four first pans of each double range are filled with the clear liquid by removing the upper plug, P. At the end of twenty-four hours the solution, diminished to about one-half of its volume, is transferred by means of siphons into the next pans of each range, and is replaced by the product of a fresh decantation from the reservoir. Twenty-four hours later, the liquor, again reduced to half its volume, is removed by means of siphons into the last two pans, while the superior two are again charged as before. The evaporation in the last two pans is continued for twenty-four hours, and the mother waters of a preceding crystallization mixed with it; the mixture then has a specific gravity of 1·07 to 1·08, at a temperature of from 173° to 176° Fahr. (78°·3 to 80° C.). The whole of this solution is then brought into the crystallizing tubs, A A A (Fig. 2), which are constructed of wood and lined with lead. Here the crystallization is effected. The produce of seventy-two hours' evaporation, derived each day from a battery of fourteen pans, affords 1¾ cwt. of saleable boracic acid. The production diminishes in rainy weather.

During evaporation abundant deposits of sulphate of lime are formed, and have to be removed. When crystallization ceases, the mother liquor is drawn off into tanks, and added to the solution contained in the last evaporating pans; the acid is placed in baskets, G (Fig. 2), to drain. It is then carried into the drying-room, D D, spread in layers on the floor, and turned from time to time. When it no longer moistens the hand on being pressed, it is formed into heaps and packed in casks. The drying-room is constructed of bricks, and has a double floor, between which the vapour of some *soffioni* is caused to circulate.

The largest lagoons, which are of an irregular circular form, are from 57 to 65 feet in diameter, and

Fig. 2.



the smallest from 13 to 16 feet; their depth varies from 5 to 8 feet. The liquid in them attains a temperature of from 200° to 203° Fahr. (93°·3 to 95° C.).

The acid contains many impurities, due to the disintegration of the strata by the jets of steam, and the infiltrations of water. The following is WITTSTEIN'S analysis of the crude acid:—

Boric acid crystallized,	76·494
Water,	6·557
Sulphuric acid,	1·322
Silica,	1·200
Sulphate of ammonium,	8·508
Sulphate of manganese,	traces.
Sulphate of magnesium,	2·632
Sulphate of calcium,	1·018
Sulphate of sodium,	0·917
Sulphate of potassium,	0·369
Ferric sulphate,	0·365
Sulphate of aluminium,	0·320
Chloride of ammonium,	0·298
Organic matter,	traces.
	100·000

Neutral borate of sodium ($NaBO_2$), is produced by heating 62 parts of crystallized boric acid, or 191 parts of crystallized borax, with 53 parts of anhydrous sodium carbonate at a heat near the melting point of silver. The unfused mass thus obtained dissolves in water with rise of temperature; and by cooling the hot, but not saturated solution, the hydrated salt crystallizes in large, oblique, rhombic prisms, with lateral angles of 130° and 70°. It has a caustic alkaline taste, and quickly absorbs carbonic acid from the air, both in the solid state and in solution; but on boiling the solutions the carbonic acid escapes. (*Watt's Dict. of Chem.* vol. i. p. 645.)

BORAX.—BIBORATE OF SODA.—*Soude boratée*, French; *Boraxsaures natron*, German; *Sodæ biboras*, Latin; *Plinius chrysocolla, Tincal.—Acid metaborate of sodium* ($Na_2B_4O_7,10H_2O = 2NaBO_2.B_2O_3, 10H_2O$). The word borax is derived from the Arabic *baurak*.

Borax has been found in some mineral waters, as those of San Restituta, or Ischia, and also in the waters of certain lakes, especially those of Thibet and Persia.

Common borax is soluble in about 12 parts of cold and 2 of boiling water. Heat resolves it into a porous, friable mass, known as *calcined borax*. At a red heat it runs into a transparent glass, which on exposure to the air becomes opaque and pulverulent on the surface. Its specific gravity in this state is 2·36.

Sulphuric acid decomposes this salt, producing sulphate of sodium and boric acid. It is also decomposed by nitric and hydrochloric acids, and by most organic acids. It is often used as a blowpipe flux,

vitrifying a great many of the metallic oxides, and giving with them beads of different colours; blue with cobalt, amethyst with manganese, green with chromium and copper.

Its taste is saline, cooling, and somewhat alkaline. It reacts on turmeric paper like an alkali. On being exposed to the air it effloresces slowly and slightly.

NATIVE BORAX—TINCAL. —This substance occurs in soft and brittle prismatic whitish crystals, occasionally possessing a tinge of blue or green, and varying from translucent, or nearly transparent, to opaque. Taste, feebly alkaline. Before the blowpipe it intumesces considerably, and then fuses into a transparent globule. It has been found in India, China, Persia, Ceylon, and South America. It has even been met with in Saxony. Gathered on the banks of small lakes holding it in solution, it was formerly imported into Europe in great quantity, under the name "tincal." It is always covered with an earthy incrustation, which smells of soap.

From a very remote period, native borax has been refined in Venice—whence the appellation, Venetian borax, equivalent to the purified salt. At a later period the process was introduced into the Dutch towns, and into France by the Brothers LECUYER. The operation has always been kept secret, nevertheless two different methods of purification have become known.

In one of these the impurities are separated by lime, tincal being softened in a small quantity of cold water, and stirred about with the gradual addition of about 1 per cent. of slaked lime. The turbid lime-water is poured off, and when on standing the impurities have settled down, the clear liquid is again poured upon the crystals. This process is repeated several times. In this manner the greater part of the soapy compound is removed; what still remains is separated by dissolving the crystals in hot water, and adding about 2 per cent. of chloride of calcium. Chloride of sodium is produced, and an insoluble lime soap, which is removed by straining, and the clear liquid is then evaporated to the consistence of 21° Beaumé, at specific gravity 1·17.

The other process consists in placing the powdered tincal in a tub, with holes pierced in the bottom, and washing it with a solution of caustic soda of 1·034 specific gravity, as long as this passes through coloured. After draining, the crystals are dissolved in water, and 12 per cent. of soda added to precipitate the foreign matters and earths; the lye must then be evaporated to the consistence of 20° Beaumé.

In both cases, the crystallization is effected in wooden vessels lined with lead, and having the form of short inverted cones. This shape is preferred, because the deposit which may form collects in the lower narrow part, and does not interfere with the crystallization. The use of lime facilitates the clarification, but may occasion a loss by the formation of insoluble borate of calcium.

Commercial borax made from boric acid has, when used by tinsmiths, notwithstanding its greater purity, one particular fault from which that obtained from tincal is free, viz., that the crystals, when heated, split in the direction of their natural cleavage, fall to pieces, and fly off from the part required to be soldered; by which means a loss is occasioned, and the work retarded. Great precautions used in the crystallization lessen this evil; but it is more effectually remedied by the addition of a small quantity of tincal before recrystallization.

So long as borax was obtained only from tincal, its price remained very high, and in 1815 it cost from 3s. to 4s. a lb. About this time began the fabrication of the salt from the boric acid of Tuscany, and carbonate of sodium. This process is now exclusively used.

It consists in treating the boric acid with crystallized carbonate of sodium at a boiling temperature; the carbonate is decomposed, carbonic acid is disengaged, biborate of sodium is formed, and crystallizes as the liquid cools. At first view this mode of preparation appears extremely simple; nevertheless, it encountered serious obstacles in the beginning from the difficulty experienced in obtaining the crystals in a solid state and of large size. PAYEN and CURTIER overcame this difficulty, and succeeded in preparing regular supplies of borax, in firm and large crystals, by performing the crystallization on a large scale, and conducting it as slowly and regularly as possible.

The manufacture will now be described. In a large wooden vessel, lined with lead and heated by steam, 23 cwts. of crystallized carbonate of sodium are dissolved in such a quantity of water that the whole forms nearly 2 tons when added to that produced by the condensation of the steam. The vats used for the dissolution of the soda are similar to A—Fig. 3. Steam enters the vat by a pipe, *c*, from the boiler, C; the tube reaches to the bottom of the vat, and terminates in a horizontal circular bend, *t*, which is pierced with holes for the elimination of the vapour. Two taps, *r* and *b*, serve to empty A; the opening, *a*, with its tube, is where the charge is introduced; this aperture is closed with a cover. Ladders, L, and balconies, M, are attached to the apparatus, for the convenience of the workmen to ascend and descend. When the solution of the soda is completed, the temperature is raised to 212° Fahr. (100° C.); boric acid is then added, in portions of not more than 8 to 10 lbs. at a time; the carbonate of sodium is decomposed, carbonic acid is disengaged with brisk effervescence, and biborate of sodium remains in solution. If too much boric acid were added at once, the evolution of carbonic acid would be so violent as to eject a portion of the liquor.

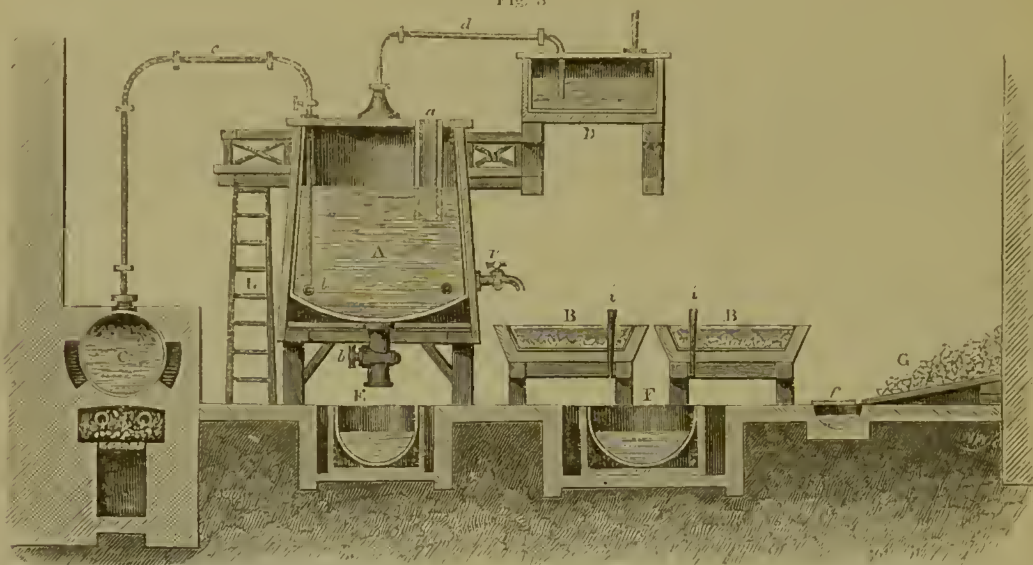
A little carbonate of ammonium, proceeding from the decomposition of the ammoniacal salts present in the crude acid, is always liberated along with the carbonic acid.

The apparatus is so constructed, that the gases and vapours pass through a tube, *d*, in the lid of the vat, to an adjacent condenser, D, containing sulphuric acid; sulphate of ammonium is thus produced, and the loss of a valuable secondary product prevented. To saturate the 23 cwts. of carbonate of sodium crystals, about a ton weight of Tuscan boric

acid, containing nearly 10 per cent. of foreign matters, is employed.

When the saturation is completed, the lye should have a specific gravity of 1·166 or 33° Twaddle. The steam is then arrested, the orifice, *a*, is closed, and the liquid is left to settle for ten or twelve hours, when the clear solution is withdrawn by the tap, *r*, into the shallow vessels, B B, lined with lead; the deposit falls through *b* into E, where it is washed, and then discarded. As soon as the crystallization is completed in the vessels, B B, the leaden plugs, *i i*, are removed, and the mother lye drawn off to the common reservoir, I, to be used for the next saturating process. The crystals are detached from the vessels, B B, and are placed upon an inclined plane or board, G, to drain: the mother liquor adhering to

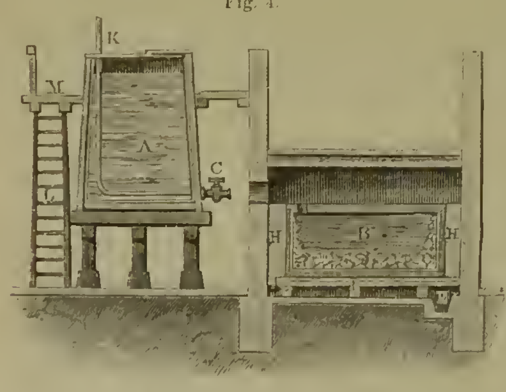
Fig. 3



the crystals falls into the channel, *f*. Borax, formed in the first crystallization, must be submitted to a succeeding operation to purify it, and transform it into large crystals.

REFINING OF BORAX.—About 9 tons of the crude borax, obtained as in the preceding, are dissolved in a vat, A (Fig. 4), by means of water, heated by steam entering by the pipe, K; the solution of

Fig. 4.



the salt is accelerated in a remarkable degree by placing the borax in a perforated cast-iron pan or sieve, raised by a crane, and suspended under the face of the liquid. The particles of fluid, as they become saturated and heavy, descend, leaving the less dense liquid in contact with the salt, till it becomes impregnated in like manner. When it is completely dissolved, some three or four hundred-weight of carbonate of soda crystals are added to the liquor, and steam again allowed to enter, until the solution has a specific gravity of 1·66; upon which it is drawn off by the tap, C, into the crystallizing vessel, B. The inclined floor, F, below B, is made of glazed stones, and any of the mother liquor which may be thrown out of the crystallizing pan, B, by the force of the liquid descending from the vat, A, flows along it to the channel, E, where it collects. The crystallizers are large wooden vessels, lined with thick sheet-lead, and about 5 or 6 feet deep, 4 feet wide, and 20 to 30 feet long; they are situated in an external box, with which, however, they are not in contact, the intermediate space being occupied by coarse wool, saw-dust, or small coal—in fact, with any matter which is a bad conductor of heat (represented in the figure by H). The vessels are besides covered over tightly with a lid made of stout boards lined with lead, in order that the cooling of the liquor may be very gradual, as this is essential for the production of large and well-defined crystals of the salt.

The crystallization should continue from twenty-five to thirty hours, according to the external temperature; it is finished when the liquor ceases to indicate a temperature of not more than 82° to 88° Fahr. (27°·7 to 31°·1 C.); at this point the mother liquor must be abstracted by means of a siphon; a man then wipes briskly the edges of the crystals with a sponge; that done, the cover is replaced, and they are left for some hours to cool, in order that they may not become friable.

The crystals which adhere strongly to the sides of the crystallizer, are detached after drying with a chisel and heavy strokes of a mallet; they are separated from one another with a small hatchet, the small crystals taken out, and are then inclosed in cases which are made to resemble the old Dutch packages.

Prismatic borax contains 47 per cent. of water, whereas octahedral borax only contains 30 per cent.; nevertheless, consumers prefer the former, partly on account of its price, being less weight for weight, and partly as matter of habit.

Various modifications have from time to time been made in the methods employed for the preparation of borax from common crystallized carbonate of sodium and crude Tuscan boric acid. KOEHNKE gives the following directions for carrying out this process: —A solution of caustic soda is made, amounting to about 170 lbs. of 1·090 to 1·095 specific gravity, which requires on the average 50 lbs. of soda and 30 lbs. of good caustic lime, the latter mixed to a paste with four times its weight of water. When the mixture has been boiled in an iron pan, and converted into caustic lye, it is carefully covered, and after the lapse of a few hours the clear solution is siphoned off, the residue again treated with a further quantity of water, well agitated, and the clear liquid again drawn off after a few hours' rest. A further quantity of water is poured over the residue, which is subsequently removed, to be employed in washing the crystals of borax obtained.

The lyes thus obtained are boiled down to 1·090–1·095 specific gravity, and then 40 lbs. of Tuscan boric acid introduced, and the whole boiled until the lye has the spec. grav. 1·175—1·180. Upon this the liquid is poured boiling-hot into a wooden tub, which is well surrounded with woollen cloths and straw, and carefully covered to retain the heat as long as possible, so that a good and regular crystallization may be effected.

After three days the first crystallization is complete. The crystals are collected and broken, washed with dilute alkaline liquid, and placed aside; the borax lye is mixed with the wash liquors and set aside, in order that it may deposit the sulphate of calcium formed, and other impurities. As soon as the liquor has become clear, it is carefully drawn off and boiled down, during which 8 lbs. more boric acid is gradually added to it, and it is then treated as before. The remaining liquid still requires from 2 to 5 lbs. boric acid. What remains after this third crystallization may be saturated with sulphuric acid, and obtained as sulphate of soda.

The product obtained must generally be twice crystallized; for which purpose it is dissolved in 2½ parts of rain-water, the lye brought by boiling to the above specific gravity, and conveyed in a state of ebullition into a wooden vessel protected from rapid cooling. The evaporation of the residuous lye is repeated. The crystallization is always terminated within two or three days. There is no need of filtration except on the last recrystallization. The product amounts, with careful treatment, to from 60 to 62 lbs. of pure borax.

The preparation of borax from crude soda and boric acid is somewhat more difficult. A solution of caustic soda is made of 1·090 (1·095 specific gravity), which contains about 100 lbs. of crude soda and from 45 to 50 lbs. caustic lime; the lie is prepared in the same manner, and from 45 to 48 lbs. of Tuscan boric acid added to it, upon which it is concentrated to specific gravity 1·175 to 1·180; in the meantime the froth is now and then removed, and finally the whole placed aside to crystallize. To the first mother liquor from 8 to 10 lbs. of boric acid are added, and to the second 2 or 3 lbs. more; frequently, however, according to the substances employed, even as much as 10 lbs. is required. The amount must be determined by a previous examination of the borax lye. The mode of operation is precisely the same as that described in the preceding method. A greater quantity of sulphate of sodium is, however, obtained on saturating the last mother liquor with sulphuric acid. The produce in crystallized borax amounts to from 80 to 90 lbs.

Octahedral borax, $(NaBO_2)_2B_2O_3,5H_2O$, was discovered by PAYEN; it possesses the advantage that when crystallized it contains half the water of the ordinary salt. It crystallizes in a more concentrated solution than that which produces prismatic borax, and within higher limits of temperature. The operation is the same as that which has just been described, except that the solution of crude borax should have a specific gravity of 1·256 to 1·30, or 50° to 60° by Twaddle, when withdrawn into the large crystallizers. The crystallization commences at a temperature of 174° Fahr. (78°·8 C.), and the octahedral borax ceases to form at 133° Fahr. (56°·1 C.); at this point, therefore the mother waters, which yield by further cooling nothing but prismatic borax, must be quickly removed.

The crystals of octahedral borax adhere strongly among themselves; they form plates of small thickness, but very hard and sonorous. Contrary to prismatic borax, they effloresce in a very moist atmosphere, or even when immersed in water; they tend, in these circumstances, to absorb a quantity of water equal to that which they already contain, and to pass to the composition of prismatic borax. In other respects, these two descriptions of borax have the same properties.

Anhydrous Borax, $(NaBO_2)_2B_2O_3$.—This salt is granular, and of a dull white colour. Its granular state renders its use convenient for the making of glass enamel, &c. SAULTERS some years ago devised the process which follows:—About 38 parts by weight of boric acid, quite pure, crystallized, and dry, are powdered and sifted; and about 45 parts in weight of fine carbonate of sodium, reduced to a powder, added, and thoroughly mixed together. The mixture is then transferred to a room, the temperature of which is raised to about 90° to 115° Fahr. (32°·2 to 46°·1 C.). It is placed in layers or beds, of about 1 inch thick, upon wooden planks. The action of the heat upon the mixture causes the boric acid to combine with the soda, and the carbonic acid is driven off from the carbonate of sodium.

together with the superabundant water contained in it, forming borax (biborate of sodium), but without any water of crystallization. The layers should be left during from twenty-four to thirty-six hours, being occasionally stirred; after which the operation is completed and the borax is ready for the market.

Fused borax, as stated, has the property, at a high temperature, of dissolving the metallic oxides and transforming them into transparent and coloured glasses.

This remarkable property, turned to advantage in blow-pipe experiments, is likewise the basis of the chief application of borax in manufacturing operations. It is well known, indeed, that this substance is indispensable in some kinds of soldering. It is applied to prevent the oxidation of the parts intended to be joined together.

For many years borax has been introduced into the composition of fine glasses and pastes; it has also been long employed in the preparation of coatings for English porcelain.

For these latter applications the borax, provided it be pure, does not require to be crystallized; it is even preferable in the anhydrous state.

Analysis.—The assay of borax may be made very easily by a process contrived by Gay-Lussac, and similar to that employed in alkalimetry. Since sulphuric acid completely decomposes biborate of sodium, if sulphuric acid of a known strength be employed, the quantity which will have been required to decompose a known weight of borax will indicate the quantity of soda contained in the salt; and, therefore, the proportion of borax which corresponds to that quantity of soda may be readily calculated.

The *modus operandi* is as follows:—Dissolve 100 grains of the borax under examination in about 1000 grains-measures of pure water, with the help of heat, and add thereto a few drops of tincture of litmus, so as to impart a blue tinge to the solution. This done, pour into an alkalimeter 1000 grains-measures of test-sulphuric acid, of specific gravity 1·032 (1000 grains-measures contain one equivalent of dry acid, and can, therefore, neutralize one equivalent of each base), and add it gradually to the solution of the borax. The liquid at first assumes a fine purplish hue, and at last one or two drops of the test-sulphuric acid in excess changes it into the characteristic red colour, which indicates that the point of saturation is obtained. In order, however, to detect this change of colour more easily, Gay-Lussac recommends the tinging of a similar quantity of water reddened by litmus, with two drops of sulphuric acid, and the comparison of the tint of this liquor with that of the solution of borax under examination. As the boric acid contained in the hot solution of borax, and which is deposited when the point of saturation is attained, interferes with the ready appreciation of the changes of colour, the solution should be allowed to cool before adding the last drops of acid. When the tinge produced in the borax liquor is exactly like that of the coloured water kept for comparison, the operator reads off the number of divisions of the test acid employed, and then calculates therefrom the value of the borax assayed. The indication is a little too high, because it is necessary to pour a slight excess of acid to produce a distinct reddening, and it is therefore customary to deduct three drops from the number indicated by the alkalimeter. The number of divisions represents the quantity of real soda contained, and from this the operator may easily calculate the quantity of the corresponding amount of boric acid.

The adulterations generally consist of common salt and alum. These impurities may be easily detected: the first, by solution of nitrate of silver, which will immediately produce a white curdy precipitate of chloride of silver, insoluble in nitric acid, soluble in a slight excess of ammonia, and which may be separated by filtering, or by decantation after it has well settled; the second, by the white bulky precipitate which ammonia produces when poured in the liquor, which precipitate is soluble in a solution of caustic potassa. The adulteration of borax with alum is sometimes so considerable, that on adding ammonia the whole solution stiffens into a thick jelly. The solution, if it contains much alum, reddens the tincture of litmus, whilst that of borax, on the contrary, renders reddened litmus paper blue again. If the borax has been falsified with one-tenth part of its weight of alum, it does not completely dissolve in water; that is to say, the liquor remains turbid, and a slight whitish sediment settles down in the glass.

Boric acid can be estimated quantitatively, in its aqueous solution, by the addition of a weighed quantity of a fixed alkaline carbonate. This method is somewhat tedious, and requires much time and attention. Carbonate of sodium is weighed in the fused state, in amount about one and a half times that of the boric acid supposed to be present in the solution. It is dissolved in the solution, and the whole evaporated at a gentle heat. At the ordinary temperature carbonic acid is not expelled from the carbonated alkalies by the free boric acid; and at a higher temperature, as also on evaporation, only in a very slight degree; it is only after the whole has been evaporated to dryness, and the dry mass is strongly heated, that any evolution of carbonic acid takes place, at which time it is necessary to be particularly careful. With a strong heat the mixture is liquid, but at a lower temperature, only tenacious. If it be fused at a white heat a constant weight is obtained on cooling, which does not vary even after long standing; but if the crucible be exposed to a moderate heat, after having been previously exposed to a strong red one, it increases in weight.

The carbonic acid in the fused mass is now estimated. If from the weight of the fused mass, the amount of soda in the carbonate of sodium originally employed be subtracted, and that of the carbonic acid which has escaped during the experiment, the quantity of boric acid is obtained with great accuracy.

The best and most accurate method of separating boric acid from bases is by means of hydrofluoric and sulphuric acids, when the boric acid is expelled as fluoride of borium, and the bases are obtained in

the state of sulphates. The finely powdered borate is digested in a platinum dish with hydrofluoric acid, and pure strong sulphuric acid afterwards added. The whole is then heated at first gently, but afterwards more strongly. The boric acid goes off in the form of fluoride of boron. The base remains as sulphate, which is estimated, and the boric acid determined by difference. Since boric acid does not form with any metal a compound which is entirely insoluble in water, no direct method of estimating this acid is as yet known. The only compound, by means of which it may be proximately separated, is the borofluoride of potassium; this salt is very sparingly soluble, and resembles the silicofluoride of potassium, and like it is insoluble in alcohol. It is more soluble in a solution of chloride of ammonium than in pure water. A great number of experiments has shown that it is not possible to separate boric acid, quantitatively, as borofluoride from its solution.

BORON.—This element was discovered in 1808 by GAY LUSSAC and THÉNARD, and about the same time by DAVY. The probability of its belonging to the same group as silicon and carbon was insisted on by DUMAS in 1840; and the fact was afterwards established by ST. CLAIRE DEVILLE and WÖHLER.

Boron has been obtained in three different forms, viz., amorphous, graphitoïdal, and adamantine.

Amorphous Boron.—GAY LUSSAC, THÉNARD, and DAVY, obtained this substance by the action of potassium at a high temperature upon anhydrous boracic acid (now termed boric oxide, or boric anhydride (B_2O_3), by hydration boric oxide is converted into boracic acid, *i.e.*, boric acid, or hydrogen borate, H_3BO_3). The boracic acid was fused in a glass tube with an equal weight of potassium in small pieces; on boiling the fused mass with very dilute hydrochloric acid, washing with water and drying, a very small quantity of boron was obtained.

R. D. THOMSON mixed the potassium and anhydrous boracic acid together only after the former had been freed as completely as possible from hydrate, and the latter had been most completely dried; by this means he increased the product.

SAINT CLAIRE DEVILLE and WÖHLER, however, were the first chemists to produce boron in any considerable quantity. In the "Ann. de Chimie," vol. lii. p. 64, they describe their process thus:—We prepare boron by a process so simple and rapid that we have been able to use nearly a kilogramme (2·2 lbs.) of the element in experiments upon its nature and properties.

Ten parts of fused boracic acid coarsely powdered are mixed with 6 parts of sodium in small pieces, and the whole heated to redness in an iron crucible, and the mass immediately covered with 4 to 5 parts of common salt, and the crucible closed with an iron lid.

Great care must be taken to avoid the introduction of any siliceous matter, as in that case silicon would be at the same time produced, and would be hard to separate.

The addition of the sodium chloride is to render the slag of borax and boracic acid more fusible. The reaction is complete so soon as a slight crepitation is perceived. The fused mass is then agitated with an iron rod and poured into a deep vessel containing water, strongly acidulated with hydrochloric acid.

The mixture is rapidly disintegrated by the acidulated water, and the boron for the most part sinks to the bottom of the vessel. The process is repeated several times, the same water being used each time, until it becomes strongly heated by successive additions of the melted flux. The whole is then filtered and the boron washed, first with acidulated water, and afterwards with pure water. The last washings are apt to contain boron. From these it can be thrown down by addition of hydrochloric acid as a flocculent very combustible powder. (To avoid this loss it is better to wash with a weak solution of sal-ammoniac, instead of pure water, afterwards removing the ammonium salt with alcohol.)

The boron is then dried in the air on porous tiles at the ordinary temperature. The slightest elevation of temperature suffices to induce incandescence, upon which the boron takes fire, and burns into boric oxide (anhydrous boracic acid.)

Amorphous boron is a greenish powder without taste or smell, but which stains the fingers; it is a non-conductor of electricity. Heated in *vacuo*, or in gases with which it does not unite, it undergoes no change even at a white heat. In pure water it is slightly soluble, but not in water containing acids or salts. Burnt in oxygen, boric anhydride (B_2O_3), its only known combination with oxygen, is produced. Amorphous boron decomposes sulphuric acid when heated with it, and nitric acid even in the cold, forming boric acid. It also decomposes all the salts of the alkaline metals, sometimes with incandescence, and in the case of the nitrates with explosion.

Graphitoidal Boron.—Chloride of boron is first prepared by passing chlorine gas over amorphous boron in a combustion tube gently heated. The vapours of the chloride are then conveyed through a caoutchouc connecting tube to a porcelain tube heated to bright redness, within which is a small boat containing aluminium. A certain quantity of chloride of aluminium is immediately formed and volatilized, and at the same time boride of aluminium takes the place of the metallic aluminium.

Aluminium boride can also be obtained by heating together aluminium, fused borax, and cryolite, with a flux of potassium and sodium chloride. A large excess of aluminium is required beyond that necessary for the reaction itself.

Or, by fusing together 15 parts of anhydrous boracic acid, 10 of fluor spar, and 2 of aluminium.

On dissolving the aluminium boride, prepared by one of these methods, in hydrochloric acid, or soda solution, thin hexagonal tablets of graphitoidal boron make their appearance.

Graphitoidal boron is semi-metallic, resembling crystalline ferric oxide; it has a coppery lustre, and is completely opaque. Heated to redness in air it neither oxidizes nor undergoes any other change. It is insoluble in most acids, and in all alkalies.

Adamantine Boron.—This, the third state of the element, is to amorphous boron what the diamond is to common charcoal. It is prepared by the mutual action of aluminium and boracic anhydride.

A charcoal crucible with a close-fitting cover is fitted within a plumbago crucible. In the inner vessel are put 80 grammes of aluminium, and 100 grammes of fused boracic acid in small pieces, the lids closed, and the whole placed in a blast furnace of sufficient power to melt nickel. The temperature is maintained at its maximum for about five hours, the furnace being meantime well clinkered. After cooling, the crucible is broken, and within it are found two distinct layers, the one vitreous and consisting of boracic acid and aluminium, the other a metallic, iron-grey, spongy mass. This is aluminium penetrated throughout its mass with crystals of the diamond-like boron.

The metallic part of the contents are then treated with boiling soda liquor, which dissolves the aluminium; next with hydrochloric acid to get rid of the iron; and finally with a mixture of hydrofluoric and nitric acids to extract any possible traces of silicon. The crystals of boron are, however, still mixed with graphitoidal boron and aluminium; the former is separated by levigation, the latter by careful selection.

Adamantine boron has been heated to the fusing point of iridium without showing any signs of change. It resists oxygen up to the temperature at which the diamond burns; it then oxidizes and becomes coated with a film of boracic acid, which stops all further action.

Chlorine, on the other hand, acts upon it with great energy at a dull red heat, converting it into vapour of chloride of boron.

Heated before the blowpipe on platinum foil, boron immediately determines the fusion of the platinum, forming with it a boride.

The specific gravity of crystalline boron is 2·68. These crystals refract light very powerfully, and are nearly as hard as the diamond. They are octahedra, belonging to the pyramidal or square prismatic system.

BORIC OXIDE—*Boric Anhydride. Anhydrous boric (or boracic) acid. Oxide of boron* (B_2O_3).—This is the only known compound of boron with oxygen.

It is readily formed by fusing boric (*i.e.*, boracic) acid, which is the hydrated oxide. The water volatilizes, and a glassy mass is produced, which is known as vitreous boric or boracic acid. According to DUMAS this boric glass cracks spontaneously on cooling, each fracture being accompanied by a flash of light. The specific gravity is 1·83.

Boric anhydride has a bitter taste, is inodorous, and is very soluble in water, forming boric acid. It dissolves also in alcohol, producing a solution which burns with a green flame.

The volatile product which is formed under these circumstances is in reality a boric ether. The presence of a metallic oxide interferes with the colouration, because in that case no ether is formed.

Boric anhydride at its fusing point unites directly with metallic oxides. It decomposes, by fusion with them, carbonates, nitrates, sulphates, and salts of all acids more easily volatilized than itself. Boric oxide loses its transparency when exposed to the air, and becomes covered with a coating of its hydrate, boric acid.

BREAD.—*Pain*, French; *brod*, German; *panis*, Latin.

The material part of grain, which by conversion into bread is rendered useful as a nutritive substance, is composed of nitrogenous substances (chiefly vegetable fibrin) and non-nitrogenous substances, (principally starch), with varying quantities of dextrin and sugar, and inorganic salts, which are mostly phosphates. Of these the nitrogenous constituents chiefly produce blood, and are therefore the most nutritive; while the organic portion of the latter constituents is almost exclusively devoted to maintaining the heat of the body, and is consequently called respiratory food.

HORSFORD, in investigating the relative values of different substances as articles of food, tabulated the annexed results for various kinds of wheat, which show the quantity of nitrogen in each when in the fresh state; *i.e.*, their relative nutritive power:—

Horsford.	Per centage of nitrogen.	Equivalents or weights for an equal amount of nutritive power.	Per centage of water.	Practical equivalents.
Talavera wheat from Hohenheim,	2·59	100	15·43	100
Whittington,	2·68		13·93	
Sandomierz,	2·69		15·48	
Wheaten flour from Vienna, No. 1,	3·00	90	13·85	—
" " " 2,	2·12		13·65	
" " " 3,	3·44		12·73	
Common winter wheat	2·79	104	13·80	102
One-grained wheat—Triticum monococcum—from Giessen,	2·07	128	14·40	124

The fourth column in the above table indicates the practical equivalents of the nutritive powers of these substances, as ascertained by BOUSSINGAULT'S experiments on the feeding of cattle.

Wheat contains more nitrogen than any of the other cereals. As cultivated in this country, it is of several kinds, which take their rise from that known as *Triticum vulgare;* there are two other sorts, the *Triticum æstivum*, or summer wheat; and the *Triticum hibernum*, or winter wheat; and these again, from intermixture and various other causes, are broken up into separate species. *Triticum æstivum* is generally tilled in spring, and the proper season for sowing the winter wheat is in autumn.

Wheat is composed of an exterior integument or shell, covering the nourishing matters; the shell constitutes from 14 to 16 per cent. of its weight when the grain is good, but the proportion is greater as it is poorer. It generally happens that no more than the one-tenth, and frequently only about one-eighth or one-ninth, is removed by grinding.

The floury part of the grain is composed of vegetable fibrin, gluten, albumen, starch, dextrin, glucose, water, and inorganic salts. These constituents are

divided into the nitrogenous, which embrace the grape sugar, vegetable fibrin, albumen, and oil; and the non-nitrogenous, which include the starch sugar, gum, and inorganic salts. Flour, when kneaded with a little water—or better, when a small stream of water has been directed upon it, whilst supported by a thin cloth—becomes entirely disintegrated, in consequence of the soluble portions being carried away in the water, while the small starch granules are mechanically taken up, and there remains a tough substance unaffected by water. At first the water, as it percolates through the cloth, has a milky appearance, and the matter upon the filter or cloth becomes shorter and more porous up to a certain period; as the filtrate passes off clearer, the remaining mass agglutinates into a compact body, which is known as *crude gluten*, but really consists of vegetable fibrin, held together by *gluten* or *gliadin;* it also contains some fatty matter. Crude gluten does not swell when treated with water, but combines with a definite quantity, acquiring a certain degree of tenacity, which, however, is not increased by further addition of water; it is not liable to decomposition for some time, and is very adhesive to solid bodies, such as the sides of vessels, paper, linen, &c., whenever it comes in contact with them; it may, however, be detached by immersion in water, or, in the case of linen or cloth, by moistening the contrary side. Boiling alcohol readily separates the crude gluten into a soluble and an insoluble substance; the insoluble is pure vegetable fibrin, and the soluble contains vegetable gliadin, to which the adhesive property of the crude gluten is attributed: by treating the latter with ammonia, the gliadin is dissolved and the fibrin remains. No cereal has so much gliadin as wheat; hence the superior tenacity of wheaten dough.

The results obtained by PAYEN show the amount of gluten to be from 9 to 22 per cent.; and during his investigation he discovered the interesting fact, that the quantity of gluten diminishes towards the heart of the seed. From this the conclusion follows, that the part of the grain in immediate contact with the integumental coating, being richest in this principle, is more nourishing as food than any other portion of the wheat grain. FURSTENBERG found corresponding results when analyzing wheat bran: it contained—

Flour, Organic		Gluten,	10·84	12·44
		Albumen,	1·60	
		Starch,	22·66	41·06
		Gum,	5·28	
		Oil or fat,	2·82	
		Water,	10·30	
Husk	Organic, or Ligneous matter,			43·98
	Inorganic	Chloride of potassium,		0·23
		Sulphate of potassa,		0·24
		Phosphate of magnesia,		0·93
		Carbonate of lime,		0·37
		Silica,		0·75
				100·00

The older chemists ascertained the amount of gluten, by mechanical washing, to be from 8 to 24 per cent., and the starch from 66 to 67 per cent.

Could the operations of the miller be brought to that state of perfection which would insure the separation of the husks, a flour containing 30 per cent. of gluten and albumen—a quantity two-fifths to one half greater than the yield from ordinary flour—would be obtained. From this it is evident that a great waste of valuable ingredients is incurred by the present process of grinding, which leaves much of the most nutritive part of the food (*i.e.*, its nitrogenous constituents) in the bran, which is composed of—

	Per cent.
Water,	13·1
Albumen—coagulated,	19·3
Fatty matter,	4·7
Husk and a little starch,	55·6
Saline matter—ash,	7·3
	100·0

Considerably more oil is found in the husk than in the interior of the grain, as the table appended shows:—

	Oil per cent.
Fine flour,	1·05
Boxings,	2·36
Pollard or sharps,	3·56
Bran,	3·25

Starch is present in considerable quantities in wheat flour, and indeed in all the cereals; it deposits from the solution obtained on washing the dough, as before noticed, with water. Some time is allowed for the starch to separate completely, when it forms a concrete granular cake on the bottom of the vessel. Besides starch, albumen, glucose, and dextrin, similar principles and inorganic salts are found in the aqueous extract.

JOHNSTON's table of the relative quantity of ash or mineral constituents, yielded by different samples of ground wheat from the localities named, is annexed:—

	Ash in a hundred parts of dry			
	Fine flour.	Boxings.	Sharps.	Bran.
Sunderland Bridge, near Durham,	1·24	4·0	5·8	6·9
Kimblesworth,	1·15	3·8	4·9	6·7
Houghall,	0·96	3·0	5·6	7·1
Plawsworth,	0·93	2·7	5·5	7·6
Stettin,	1·01	4·5	6·2	6·9
Odessa,	1·01	4·9	6·6	8·0

The subjoined table represents the inorganic constituents of several varieties of wheat, according to recent analyses performed by different chemists.

When wheat grain is incinerated, the amount of the ash remaining is about 2¼ per cent. from dry grain, but only 2 per cent. is obtained when the grain is fresh; of this residuary ash the preceding table shows the composition in 100 parts. The apparent irregularity observed in the composition of the ash from various samples, is occasioned by the well-known property of plants, of assimilating different but analogous constituents from the soil, when the true body peculiar to the grain is wanting, either through exhaustion of the soil or otherwise.

TABLE SHOWING THE COMPOSITION OF THE ASHES OF WHEAT, ACCORDING TO RECENT ANALYSES.

Plants, or parts of plants.	Ashes in 100 parts of crop as taken from ground.	Ashes in dry plants, when all the water is artificially removed.	Potassa.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Peroxide of iron.	Chloride of sodium.	Locality of plant	Analyst.
Wheat of Foreign growth. Grain, red,.....	—	—	21·87	15·75	9·60	1·93	49·32	0·17	—	1·96	—	Giessen.	Will and Fresenius
Grain, white, ..	—	—	33·84	—	13·54	3·09	49·21	—	—	0·31	—	Giessen.	,,
,, ..	—	—	25·90	0·44	6·27	1·92	60·39	—	3·37	1·33	—	Leipsic.	Schmidt.
,, ..	—	—	6·43	27·79	12·98	3·91	46·14	0·27	0·42	0·50	—	[1]Holland.	Bichon.
,, ..	—	—	24·17	10·31	13·57	3·01	45·53	—	1·91	0·52	—	Solz, Hesse-Cassel.	Thon.
,, ..	—	—	30·12	—	16·26	3·00	48·30	1·01	1·31	—	—	Bechelbronn, Alsace.	Boussingault.
,, ..	1·55	1·74	32·39	2·32	13·94	3·47	43·47	0·35	3·05	0·97	—	France.	Way and Ogston.
,, ..	1·50	1·68	30·30	1·00	14·28	3·17	45·80	—	4·48	0·89	—	Odessa.	"
,, ..	1·7	1·88	35·77	9·06	11·09	2·05	34·44	0·24	4·00	—	—	Adrianople.	"
,, ..	1·97	2·19	36·60	0·53	11·12	4·34	41·03	0·18	4·97	1·18	—	Egypt.	"
Hopeton wheat, grown in England. ,, ..	1·81	2·05	33·15	—	12·71	3·20	47·00	0·24	2·84	0·60	—	[2]Cirencester.	"
,, ..	1·51	1·69	33·00	2·07	13·99	2·82	46·18	0·48	1·42	—	—	[3] "	"
,, ..	1·18	1·70	27·06	4·08	13·57	4·29	41·22	1·91	5·91	1·36	—	[4] "	"
,, ..	1·56	1·72	32·24	4·06	10·94	2·06	45·73	0·32	2·28	2·04	0·27	[5]Dorset.	"
,, ..	1·63	1·84	29·92	6·08	12·43	1·83	45·30	0·59	4·13	1·76	0·64	[6] "	"
,, ..	1·61	1·81	36·43	4·62	13·26	1·32	39·97	0·15	4·23	—	—	[7]Gloucestershire.	"
,, ..	1·63	1·81	32·05	3·38	9·32	4·43	47·33	—	3·05	0·35	—	[8] "	"
,, ..	1·71	1·94	34·51	1·87	11·69	1·80	43·98	0·21	5·63	0·29	—	[9] "	"
,, ..	1·69	1·92	30·32	0·07	12·38	2·51	49·22	0·18	3·60	0·08	1·60	[10] "	"
,, ..	1·76	2·01	32·14	2·14	9·67	8·21	44·41	—	3·29	0·08	—	[11] "	"
Red-straw white wheat, grown in England. ,, ..	1·70	1·91	31·00	2·54	9·53	1·45	40·91	0·08	9·71	3·34	0·31	[12]Sutton Waldron.	"
,, ..	1·72	1·95	29·75	0·64	13·75	3·27	49·58	0·60	2·14	0·23	—	[13]Gloucestershire.	"
,, ..	1·73	1·97	29·91	1·87	14·05	3·39	47·44	—	2·63	0·67	—	[14] "	"
,, ..	1·61	1·81	30·13	1·25	11·46	6·87	47·38	0·07	2·76	0·07	—	[15] "	"
,, ..	1·60	1·80	30·02	3·82	13·39	1·15	46·79	—	3·89	0·91	—	[16] "	"
,, ..	1·90	2·13	29·17	2·20	14·22	5·05	46·61	0·44	2·17	0·09	—	[17] "	"
,, ..	1·73	1·96	26·70	2·12	12·76	6·78	46·99	0·24	2·05	2·32	—	[18] "	"
Old red Lammas wheat,	1·84	2·10	34·26	4·53	9·56	3·21	40·57	0·32	5·46	2·06	—	[19]Wantage.	"
Spalding wheat,......	1·81	2·05	29·76	5·26	11·06	2·88	48·21	0·11	2·23	0·23	—	[20]Cirencester.	"
Creeping wheat,......	1·73	1·95	31·18	2·42	12·35	1·50	46·49	0·61	5·20	0·22	—	[21]Hackness.	"
,, ..	1·65	1·85	28·89	1·40	13·06	6·76	45·64	1·55	2·55	0·11	—	[22] "	"
,, ..	1·71	1·91	30·94	1·28	12·74	3·72	48·53	—	1·34	1·40	—	[23] "	"
Mean of the 32 analyses	1·67	1·93	29·97	3·90	12·30	3·40	46·00	0·33	3·35	0·79	0·90	"	"

REMARKS.

1 This wheat being grown near the sea, part of the potassa is substituted by soda.
2 Grown on calcareous stone-brash on the oolite.
3 Grown on calcareous brash and clay.
4 The seed from which the two previous specimens were grown.
5. Loamy soil, on the clay below the chalk.
6. Calcareous soil.
7. Siliceous soil lying on limestone.
8. Clayey soil on the Silurian rocks.
9. Sandy soil on the Silurian rocks.
10. Clayey soil on the Silurian rocks.
11. Sandy soil on old red sandstone.
12. Loamy soil on the green-sand.
13. Sandy loam on the old red sandstone.
14. Do. do.
15. Calcareous soil on the mountain limestone.
16. Clayey loam on Ludlow rock. (?)
17. Sandy calcareous soil—Silurian
18. Calcareous clay on magnesian limestone.
19. Very calcareous soil on the chalk.
20. Calcareous stone-brash; great oolite.
21. Soil, clayey sand.
22. Do. do.
23 Soil, calcareous rubble, Oxford clay.

The proportionate quantities of gluten, albumen, starch, fibrin, &c., in wheat, is exhibited in the annexed analyses, the grain being dried at 212° Fahr. (100° C.).

	Wheat from Hohenheim.			Triticum monococcum from Giessen.	Wheat from Vienna.		
	Talavera.	Whittington.	Sandomierz.		No 1.	No. 2.	No. 3.
Gluten and albumen, ...	16·52	17·09	17·15	13·20	19·15	13·53	21·93
Starch,..................................	56·25	52·15	53·37	54·63	65·68	67·17	57·45
Fibrin, gum, sugar,..................	24·53	26·53	25·52	29·89	14·09	18·20	20·58
Ash,......................................	2·80	3·13	2·40	2·10	0·70	0·66	1·11
	100·10	99·20	98·41	99·82	99·62	99·56	101·07
Per centage of moisture in the grain,....	15·43	13·93	15·48	14·40	13·83	13·65	12·73

The following are the results of analyses of wheat by PELIGOT:—

	No 1. White Flemish wheat 1841.	No. 2 Hardy wheat 1843.	No 3. Touselle blanch from Provence.—1842.	No 4. Odessa wheat. Poland.	No 5. Blé Hérisson. 1842.	No. 6. Poulard roux. 1840.	No 7. Poulard bleu Conique 1844.	No. 8. Poulard bleu Conique. Very dry year—1846	No. 9. Mitadin du Midi.	No. 10. Polish wheat. 1844.	No. 11. Hungarian wheat. 1846.	No 12. Egyptian wheat.	No 13. Spanish wheat.	No 14 Tanga rock wheat.
Water,..............................	14·6	13·6	14·6	15·2	13·2	13·9	14·4	13·2	13·6	13·2	14·5	13·5	15·2	14·8
Fatty matters, ...	1·0	1·1	1·3	1·5	1·2	1·0	1·0	1·2	1·1	1·5	1·1	1·1	1·8	1·9
Nitrogenous matter insoluble in water,..	8·3	10·5	8·1	12·7	10·0	8·7	13·8	16·7	14·4	19·8	11·8	19·1	8·9	12·2
Soluble nitrogenous matter—albumen,..	2·4	2·0	1·8	1·6	1·7	1·9	1·8	1·4	1·6	1·7	1·6	1·5	1·8	1·4
Soluble non-nitrogenous matter—dextrin,	9·2	10·5	8·1	6·3	6·8	7·8	7·2	5·9	6·4	6·8	5·4	6·0	7·3	7·9
Starch,..............................	62·7	60·8	66·1	61·3	67·1	66·7	59·9	59·7	59·8	55·1	65·6	58·8	63·6	57·9
Cellulose,..........................	1·8	1·5	—	—	—	—	1·5	—	1·4	—	—	—	—	2·3
Saline matter,......................	—	—	—	1·1	—	—	1·9	1·9	1·7	1·9	—	—	1·4	1·6

The cellulose and ashes, or saline ingredients, are to be deducted from numbers 3, 5, 6, 11, 12, and cellulose only from numbers 4, 8, 10, and 13.

Having thus far dwelt in detail upon wheat, on account of its greater importance in bread-making, it will be necessary to give a short sketch of the other cereals, which are also used as food in the form of bread. These are Rye, Barley, Oats, Indian corn, Rice, &c.

Rye.—This grain is very similar to wheat in its physical properties. It is the seed of the *Secale cereale*, resembling wheat in form, but rather elongated. Its cultivation in this country is not carried on to any great extent, but it forms the staple tillage in the Northern European provinces, where the soil, being sandy, is well adapted for its production.

This cereal in its cultivation is subject to many casualties, which prevent the formation of the grain; among these the "ergot" is most destructive.

In an agricultural point of view, very little has been done towards gaining a knowledge of the nature of this substance, and the treatment which affects its growth. Many consider it as a morbid alteration of the *ovarium* of the grain, caused by the puncture of an insect of the genus *musca*, and which deposits a very dark-coloured liquid. Some toxicologists rank the ergot of rye among narcotico-acrid poisons: others regard it as a poison *sui generis*. Its chronic effects have occasionally been witnessed on the Continent in an epidemic form, and they have, in some instances, been distinctly traced to its admixture with rye bread. Bonjean knew of two cases in which spontaneous gangrene was induced by bread containing this deleterious substance. Ergot of rye is extensively employed by accoucheurs to aid, and, indeed, to bring on parturition.

When rye is ground, it produces a flour like that of wheat, but considerably darker in colour. The reason of this seems to be that more of the husk of the grain is carried through the mill and passes into the flour. The analysis of rye flour is conducted in a similar manner to that of wheat flour. On washing with water the pasty mass of rye flour, however, no residue remains, as it is entirely carried off mechanically in the solution; hence, the gluten of rye flour cannot be separated from the starch, as can be done with that of wheat. The dissimilarity of these grains in respect to the behaviour of the flour with water, seems to depend upon the different natures of their gluten; according to Heldt, the gluten of rye contains very little fibrin, but a nitrogenous substance, which he names vegetable gelatin.

The analyses of rye given below, show the nourishing power of this grain:—

	Rye flour.			Rye and bran.
	Einhof.	Greif	Boussingault	Flour.
Gluten,	9·48	12·8	10·5	3·96
Albumen,	3·28	3·0		3·31
Starch,	61·07	58·8	61·0	65·32
Sugar,	3·28	10 4	3·0	—
Gum,	11·09	7·2	11·0	3·78
Woody fibre,	6·38	—	6·0	—
			Fat.	
Acid unexamined, loss,	5·62	7·8	3·5	1·92
	100·20	100·0	98·0	78·32

Furstenberg.	Bran
Organic matter,	6·18
Chloride of potassium,	0·01
Phosphate of magnesia,	0·39
Silica,	0·12
	6·70
Water,	14·98
Total constituents of the flour,	78·32
	100·00

More accurate results may be calculated as follows, from the elementary analysis of Horsford and Krocker:—

	Dried at 212° Fahr.					
	Rye flour from Vienna.		Rye flour from Hohenheim.		Buck-wheat flour from Vienna.	Tartarian buck-wheat from Hohenheim.
	No. 1.	No 2.	Schilf.	Standen.		
Gluten and albumen,	11·92	18·60	17·73	15·76	6·88	9·94
Starch,	60·91	54·48	45·09	47·42	65·05	41·12
Woody fibre, gum, sugar,	24·74	24·49	35·77	35·25	26·47	46·26
Ash,	1·33	1·07	2·13	2·37	1·09	2·30
	98·90	98·73	101·02	100·80	99·49	102·62
Moisture in fresh substance,	13·78	14·68	13·94	13·82	15·12	14·19

The inorganic constituents of the ashes of rye are—

	Rye.		
	1. From Giessen.	2. From Cleves.	3. Kidderminster.
Potash,	31·89	11·43	33·83
Soda,	4·33	18·89	0·39
Lime,	2·84	7·05	2·61
Magnesia,	9·86	10 57	12·81
Ferric oxide,	0·80	1·90	1·04
Phosphoric acid,	46·03	57·81	39·92
Chloride of sodium,	trace	—	—
Silica,	1·42	0·69	9·22
Sulphuric acid,	0·17	0·51	0·18
Charcoal, sand, &c.,	2·66	—	—
	100·00	—	100·00

The first and second samples were analysed by Will, Fresenius, and Bichon, and the third by Way and Ogston.

Barley.—The barley mostly cultivated in Great Britain is the species known as *Hordeum distichon*, or two-eared barley. As met with in the market, the seeds are usually enveloped in their *palea* or husk; stripped of this it forms *Scotch barley*, and when the latter is rounded by peculiar means it bears the name of *pearl barley*.

The proportion of nitrogenized matter in barley is much less than in wheat; therefore the crude

gluten is rather deficient, so much so that very little remains upon washing the dough with water. The annexed analyses of this grain by EINHOF and BOUSSINGAULT show the relative proportions of water, husk, and flour in 100 parts of the grain :—

	Water.	Bran.	Flour.	
Common barley,	11·0	19·0	70·0	EINHOF.
Naked barley,..	10·0	17·0	73·0	"
Barley,.........	13·0	18·0	69·0	BOUSSINGAULT.

Barley contains about 6·24 per cent. of gluten and albumen, and 69·5 of starch, gum, and sugar. FROMBERG gives the relative proportion of nitrogenous matter in hard and soft barley, which he calculated, from the nitrogen obtained, as follows:—

Soft, or malting barley,..................	10·93
Flinty, or hard barley,....................	8·03

OATS.—Another of the cereals, and to which reference has been made, is the oat, a plant extensively cultivated in this kingdom. There are several varieties; that which is grown in this country is the kind known as the *Avena sativa*. The oat is a seed different in appearance and composition from those grains already spoken of, though the same substances are peculiar to all of them. It is of an elongated conical shape, and is inclosed in a thick husk, deprived of which it constitutes what are termed "groats;" these, crushed, produce what is known as "Embden groats," and when finely ground, oat flour or meal of a yellowish white colour. Though this does not form a dough or paste with water like wheat flour, it nevertheless contains a large amount of nitrogenous matter, which exists in the form of a peculiar body, *avenin*, similar to and probably identical with legumin.

The annexed analyses of oats give the relative amount of water, flour, and bran :—

	Water.	Bran.	Flour.
Oats, ...	—	34	66
"	21	18	62

NORTON gives the average analysis of eight samples of Scotch oats which he examined, in the annexed numbers; namely, grain, 76·28; and husk, 23·68. The maximum of husk in his analyses was 28·2, and the minimum 22·0.

The composition of French oats, including the husk, according to BOUSSINGAULT, is as follows :—

	Centesimally represented.
Starch,..................................	46·1
Gluten-avenin, albumen,................	13·7
Oil,......................................	6 7
Sugar,....................................	6·0
Gum,......................................	3·8
Husk-ash and loss,......................	23·7
	100·00

Previous to this analysis the meal was dried at 230° Fahr., and the loss of water was found to be 20·8 per cent. The investigations relative to tihs subject performed by Professors KROCKER, HORSFORD, and THOMSON, afford the following results:—

ANALYSES OF BARLEY AND OATS BY KROCKER, HORSFORD, AND THOMSON, DRIED AT 212° FAHR.

	Krocker and Horsford.		Krocker and Horsford.		Thomson.
	Winter barley, Hohenheim.	Jerusalem barley, Hohenheim.	Kamschatka oats, Hohenheim.	White oats, Hohenheim.	Barley, Scotland.
Gluten and albumen,....	17·70	14·72	17·99	12·17	15·24
Starch,.................	38·31	42·34	37·41	} 84·74	39·86
Husk, gum, sugar,.......	42·33	42·46	45·67		46·19
Ash,....................	5·52	2·84	4·14	3·09	3·26
Moisture in the grain,....	13·80	16·79	12·94	9·46	12·71

Those inorganic compounds which are necessary for the production of bone and the other inorganic parts of the animal body are supplied by the oat. The following analyses of the ashes of oats, by Messrs. WAY and OGSTON, demonstrate this point:—

ANALYSES OF THE ASH OF OATS BY MESSRS. WAY AND OGSTON.

	Hopeton oats. Grain.	Potato oats. Grain.	Polish oats. Grain.	Polish oats. Grain.	Unknown. Grain.
Potassa,....................	17·80	19·70	24·30	16·35	13·97
Soda,.......................	3·84	1·35	3·84	5·27	1·50
Lime,.......................	3·54	1·31	3·54	8·35	4·22
Magnesia,...................	7·33	8·25	7·33	5·90	8·82
Sesquioxide of iron,........	0·49	0·27	0·69	0·09	0·36
Sulphuric acid,.............	1·10	0·10	1·74	4·01	0·13
Silica,.....................	38·48	50·03	41·86	43·20	49·44
Carbonic acid,..............	—	—	—	0·59	—
Phosphoric acid,............	26·46	18·87	14·19	16·19	21·53
Chloride of sodium,.........	0·92	0·07	0·45	—	—
Loss,.......................	0·04	0·05	1·76	0·05	0·03
	100·00	100·00	100·00	100·00	100·00
Per centage of ash in the dry substance,.........	2·50	2·73	2·97	3·89	3·12
Per centage of ash in the fresh substance,.......	2·27	2·45	2 65	3·31	2·75

INDIAN CORN.—This grain, as it comes to the market, is generally of a yellowish colour, though some varieties are white; the shape of the grain is somewhat rectangular, but broader and thicker at the top; the nutritious portions are enveloped in a very thick covering.

Indian corn does not thrive in this country, but grows luxuriantly in America, and also in southern Germany and other warm climates.

When the dough of Indian corn is washed with water, like that of wheat, a glutinous residue is left, different, however, from the gluten of wheat, and characterized by its solubility in alcohol. The following elementary analyses are different

from the preceding in the amount of nutritious matters:—

	Indian meal from Hohenheim.	Indian meal from Polenta, Vienna.
Gluten and albumen,	14·66	13·65
Starch,	66·34	77·74
Husk, sugar, gum, fat,	18·18	7·16
Ash,	1·92	0·86
Water in fresh substance,	14·96	13·36

Indian corn contains more fatty matter than any other grain, and as much as 4½ per cent. of a yellow thick fluid oil.

Maize, or Indian corn, yielded 14 per cent. of water, and the dried grain upon analysis by Payen:—

	Centesimally.
Husk,	5·9
Gluten,	12·3
Starch,	71·2
Sugar and gum,	0·4
Fatty matter,	9·0
Saline matter, or ash,	1·2
	100·0

The ash of Indian corn is composed of—

	Grown in the U. States. Fromberg.	Bechelbronn. Letellier.
Potash,	26·63	30·8
Soda,	7·54	
Lime,	1·59	1·3
Magnesia,	15·44	17·0
Phosphoric acid,	39·65	50·0
Sulphuric acid,	5·54	—
Silica,	2·09	0·8
Ferric oxide,	0·60	—
Loss,	0·92	0·1
	100·00	100·0

Rice.—Two specimens of rice, examined by D'Arcet and Payen, the one from Lombardy and the other from Carolina, contained 13½ per cent. of moisture and 12 per cent. of nitrogenous matter; the method of analysis pursued, however, was calculated to give too much of the latter.

Johnston found the composition of a species of unhusked rice to be—

Husk,	20·91
Grain,	79·09
	100·00

Five varieties of rice, freed from husk, gave respectively the annexed proportions of water and ash:—

	Water.	Ash.
Madras rice,	13·5	0·85
Bengal rice,	13·1	0·45
Patna rice,	13·1	0·36
Carolina rice,	13·0	0·33
Carolina rice flour,	14·6	0·35

According to Payen, dry rice contains—

	Centesimally.
Starch,	86·9
Gluten, &c.,	7·5
Fatty matter,	0·8
Sugar and gum,	0·5
Epidermis,	3·4
Saline matter—ash,	0·9
	100·0

The following analysis of the inorganic constituents of rice shows the nature of the mineral substances contained in this grain:—

	Rice grain from Bechelbronn.	Husk.
Potash,	18·48	1·60
Soda,	10·67	1·58
Magnesia,	11·69	1·96
Lime,	1·27	1·01
Phosphoric acid,	53·36	1·86
Sulphuric acid,	—	0·92
Silica,	3·35	89·71
Ferric oxide,	0·45	0·54
	99·27	99·18

Rice contains less fatty matter than any other grain, and, as with most of the cereals described, the greater portion of it is found in the husk.

Preparation of the Corn.—The first operation is the cleaning of the grain.

Cleaning and Winnowing.—In French, American, and English steam mills the machinery for cleaning the grain is generally of three kinds; the first consists of a series of sieves, which remove the foreign materials, stones, shells, &c., and finer impurities, from the grain.

The second apparatus removes the husk of the grain, the runner being elevated so that none of the grain is reduced to powder during the action.

The third separates sand, dust, or any other dirt from the grain by attrition: to effect this a cylinder lined with brushes is made to revolve, and these, by scrubbing the grain against the cylindrical file-like surfaces of the case, effectually detach all the lighter bodies. The light dirt being disintegrated, is afterwards removed completely by a winnowing fan worked by the machinery.

Figs. 1 and 2 are drawings of an apparatus for cleaning, winnowing, and separating different kinds of grain at one process, invented by MM. Jerome Brothers, of Amiens, and used in several districts of France. Fig. 1 is a front exterior view, and Fig. 2 a vertical section made through the axis of the apparatus. The different working parts of this machine are so arranged as to occupy little space, and to effect the various operations in a steady and uniform manner, requiring but little motive power. The frame in which the whole machinery is inclosed consists of two cast-iron cases, a. The corn to be cleaned and sifted is first thrown into a hopper, b, from whence it falls into the riddle, c, by which the straws and all other bodies larger than the grain are removed. This riddling-box receives a jerking motion directly from a cam, fixed at the extremity of the horizontal iron shaft, e, which carries the vanes of what may be termed the "thrasher." The riddled corn falls by the inclined sluice, i, towards the lower part of the fixed drum, g, which is formed of rasped sheet iron, having its rough side inwards, and which, at its opposite ends, is closed with a metal grating, h. The horizontal shaft, e, carries two series of arms, *i i*, to which are attached the wooden vanes, j, and these are in like manner furnished with sheet iron rasped on the surface, so that, by the rapid rotation communicated to the axis, they beat the corn against the interior of the drum, and

raise it, while being subjected to this process of thrashing, to the upper part, whence it proceeds by the channel, K, towards the end of the machine, into the box, L, closed in front by a cover of wire gauze, through which passes the air that is driven by the vanes. All the dust which is disengaged from the corn passes from the drum through its various little openings into an exterior case, and is then delivered into a kind of trough, N, which constitutes the lower part of this exterior case. The dust is removed, when desired, by a small door of sheet iron. The cleaned corn falls from the box, L, into the riddle, O, in proportion as it is winnowed by the air from the vanes, J, which air escapes by the passage, P.

This riddle or sifter, which has for its object to separate all the small seeds and dwarf grains from the good corn, receives also, like the first riddle, a more or less energetic oscillating movement, by means of the lever, Q, which, at its lower extremity, carries a stud acted on by the cam, R, fixed near the end of the horizontal shaft, E. A spiral spring, S, the tension of which may be regulated at pleasure by the aid of an abutting screw, limits to any required extent the oscillatory movements of the riddle. All the good corn which passes out at the lower end of the riddle is delivered into the inclined sluice, U, from which it may be received into a sack; and all the refuse which has passed through the holes of the sieve descends into the receptacle, V, at the bottom of which is a door for the purpose of removing it when necessary.

Fig. 1.

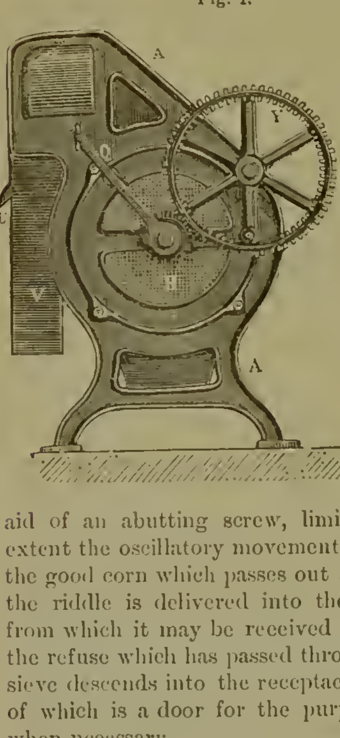
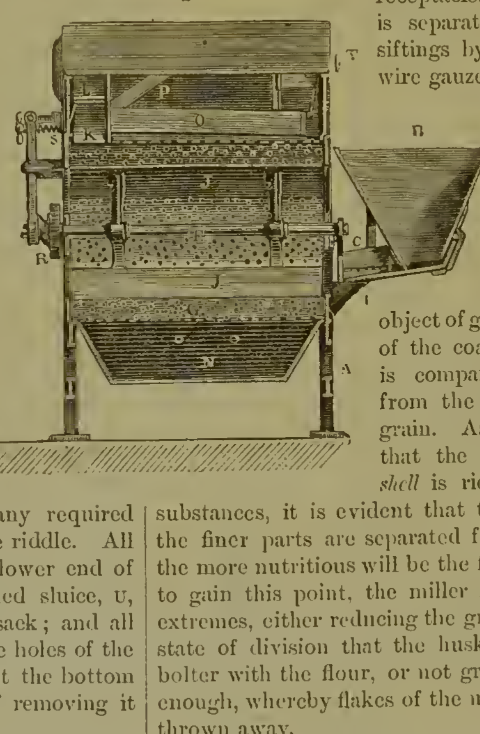


Fig 2.



When this machine is fitted to a mill where it can be driven by a constant force, a fixed cast-iron pulley, connected with the main shaft of the machinery, is mounted at the end of the horizontal shaft, E; and a loose pulley is also provided, to allow of interrupting the movement at pleasure. When, on the contrary, the apparatus is to be driven by hand, a toothed pinion is applied to the shaft, E, and this gears with a large wheel, Y, to which a handle is fitted. The teeth of this wheel are made of wood, but of a particular construction. They are dovetailed into the iron circumference of the wheel, so as that the wood is surrounded with the metal on three sides. In this way each of the teeth is solidly fixed.

The sifting process is effected by a very simple arrangement, which permits of collecting separately grains of different kinds and sizes that have been mixed together; in a word, which performs the part of a "sorter," while at the same time the work of cleaning is accomplished. This arrangement consists in placing within the riddle several pieces of wire gauze of different degrees of fineness, the one over the other, and making these correspond to the different sizes of the several kinds of grain to be collected. One piece of this gauze is fitted in the receptacle for the siftings, V; another is connected with the outside of the machine by the sluice, U. The effect produced by this arrangement is as follows:—The mixed grains of rape and poppy-seed, for example, fall on the upper wire sieve, the poppy-seed passes through and falls on the second, while the rape-seed, being larger than the poppy-seed, travels over the upper sieve and falls out at the end of the riddle into a separate receptacle. The poppy-seed is separated from the refuse siftings by the lower sieve of wire gauze, through which the latter pass and fall into the reservoir, V, while the good grain or corn arrives at the sluice, U, from which it is received into a sack.

Grinding. — The object of grinding is the division of the coating or husk, which is comparatively indigestible, from the interior part of the grain. As it has been shown that the portion nearest the *shell* is richest in nitrogenous substances, it is evident that the more completely the finer parts are separated from the integument, the more nutritious will be the flour. In attempting to gain this point, the miller frequently runs into extremes, either reducing the grain to such a minute state of division that the husk passes through the bolter with the flour, or not grinding the grain fine enough, whereby flakes of the most valuable part are thrown away.

Mills, generally speaking, contain three classes of machinery; that for the actual grinding, the hopper which supplies the grain to the stones, and the bolter and its case, where various sieves produce flour of the requisite fineness. In Germany this set is called a *gänge*. In mills lately constructed, besides the preceding being more complete, various other apparatus are appended.

In noticing the first class of machinery, the millstones claim priority. These are rarely entire, being almost always constructed of several blocks cemented together by gypsum or Portland cement, and sur-

rounded with strong iron bands. Their size varies from 3 to 5, and occasionally 7 feet in diameter. The stone should be so hard that it will not readily become smooth, yet not so hard as to render its dressing or grooving difficult. Blocks hewn out of the Rhenish lavas are preferred in Germany for their hardness and open texture; for, as the stone is abraded, the blisters break, forming a series of cavities bounded by sharp edges, which partially supply the place of artificial grooves. The best millstones in this country are made from a very hard silicious rock, known by the name of *Buhr* or *Burr-stone*, and found only, in any quantity, in the vicinity of Paris, and a few other places in France. It is imported into this country as ballast. Its pores are very large, often requiring to be filled with alum and grit, yet, at the same time, it is so durable, that a pair of stones have been known to last in active operation for twenty years.

In cutting them, the surfaces of contact are not left smooth, but are indented to a depth of from a quarter to one-eighth of an inch, in a series of lines diverging from the centre to the circumference. This grooving is called the "dressing." If the stones were without the indentations, the grain would only be crushed, in which state it would clog and adhere to them, thus offering a great obstruction to their rotatory motion. In such a case the portions thrown out, instead of being properly separated from the husk, are found so blended together with it, unless the corn is completely dried, that it is impossible to detach, economically, the valuable parts of the grain. Even if kiln-dried grain was used, the operation could not be conducted with smooth-surfaced stones, on account of the heat which close friction occasions in the flour; besides this, a glaze or polish would be given to it, by which its quality would be impaired.

There are various methods of grooving the stones. Fig. 3 represents the American plan of dressing,

Fig. 3.

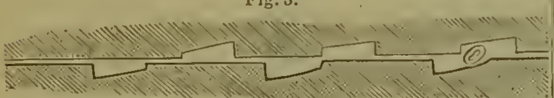
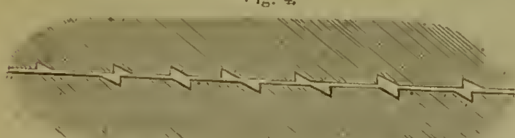


Fig. 4.



which is considered the best. The grooves in the top stone, or "runner," are so adapted to the lower or "bedstone," that, when motion is communicated to the former, an action takes place between the identations of both stones, similar to that of shears or scissors. In dressing, the furrows are never made perpendicularly at both sides, but at one side the groove is cut vertically, and the opposite side diverges from this straight line at an angle of about 45°. Both stones are grooved in the same manner and direction, but when the runner is afterwards placed in its working position, the course of the stones, as also that of the channels, is reversed, and both the edges meeting in opposition, cut the intermediate grain into fragments; these, in being swept over the "landings," or smooth spaces of the mill-stones, are ground fine.

Sometimes, instead of the channels being curvilinear, as in the preceding woodcut, they are straight, as in the annexed sketch of the stones of a French power mill—Fig. 4. A similar dressing is practised in this country, but the number of long or "master furrows" is generally eight, and the shorter or auxiliary ones twenty-four.

Fig. 5.

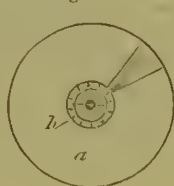
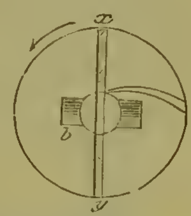


Fig. 6.



In ordinary mills each stone is, for the most part, dressed differently (Figs. 5 and 6), the runner, *b*, having spiral channels from the centre to the circumference, while those of the bedstone, *a*, are radii. A large diametrical canal, *x y*, is cut in the runner for admitting air. The central circles, *h b*, in these engravings show the spaces through which

Fig. 7.

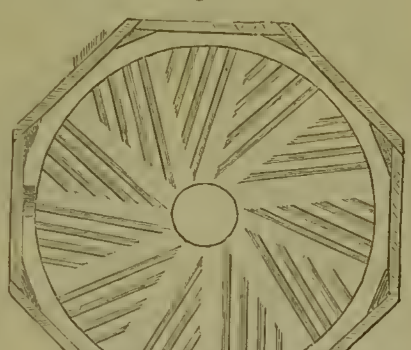
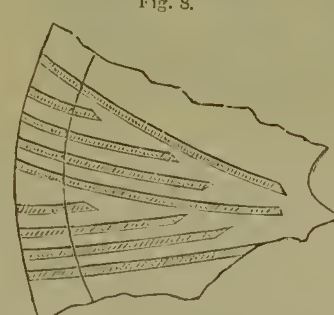


Fig. 8.



the spindles pass, the arrow shows the direction in which the runner travels. Figs. 7 and 8 show the arrangement of the furrows.

When the stones are again dressed, the furrows are reversed, the spiral ones being cut into the bedstone, and the radii into the runner.

The use of the hopper and bolter will be explained

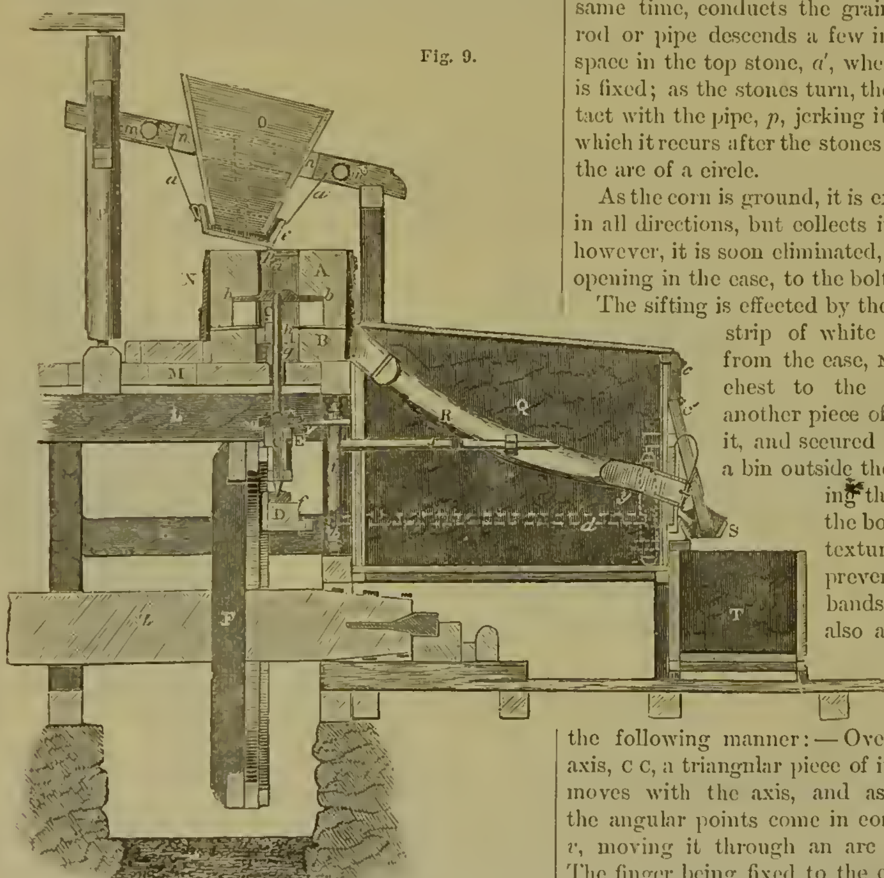
when reference is made to the general construction and employment of each part of the mill.

Mills are often differently made, but, excepting the motive power, the same principles are referrible to them all. Wind, water, or steam is used, the choice being dependent, to a great extent, upon the position of the mill-house.

Fig. 9 is a section of an ordinary mill, moved by a large water-wheel, not shown in the engraving.

The shaft from the water-wheel is generally a large beam of wood, represented in the cut by Z; upon this the second or principal wheel, F, is constructed, the cogs of which act upon the fly, E, of the spindle, C, which is an iron bar forming the axis of the stones;

Fig. 9.



its lower end is conical, and rests upon a bed of steel, *f*, which is supported by the beam, D, fixed upon other cross-beams, G and L, forming a kind of leverage, whereby the beam, D, and spindle, C, are depressed or elevated as required. The stones which grind the corn are A and B, the latter being the bedstone, in the middle of which, as at *g*, the iron bar, C, passes through a tightly-fitted packing-box, *h*, to the runner in which it is fastened, by fixing in the circular space cut away—about 6 or 8 inches in diameter—an iron bar, *b b*, having a rectangular hole in the centre, into which the end of the axis, C, exactly fits. This apparatus is called the "ryne."

A case, N, envelopes both stones, to protect them from dirt, and to prevent the flour from being scattered about by the centrifugal force of the runner. Over that part of the machinery already described a prismoidal-shaped hopper, O, is supported upon a frame, *n n*; into this box the grain is emptied, whence it is supplied to the stones by the motive power of the mill. The bottom of the hopper is received into a movable box, *e*, called a *shoe*, which is suspended by the cords, *a a*, passing round the fluted rollers, *m m*, in such a manner that the orifice in the bottom is partially closed, allowing no more grain to pass from it than is necessary to supply the stones. The corn is not let in at one place, but is made to enter on each side of the ryne by a shaking motion communicated to the shoe by the iron pipe, *p*, which, at the same time, conducts the grain to the runner. The rod or pipe descends a few inches into the circular space in the top stone, *a'*, where a serrated iron ring is fixed; as the stones turn, the notches come in contact with the pipe, *p*, jerking it out of its position, to which it recurs after the stones have revolved through the arc of a circle.

As the corn is ground, it is expelled from the stones in all directions, but collects in the case, N, whence, however, it is soon eliminated, through a rectangular opening in the case, to the bolter in the flour-box, Q. The sifting is effected by the bag, R, attached by a strip of white leather to the outlet from the case, N, passing through the chest to the opposite end, where another piece of leather is fastened to it, and secured to a pipe opening into a bin outside the flour-box for receiving the bran. The cloth of the bolter is of such a fibrous texture and stiffness as to prevent it collapsing; the bands of leather at each end also assisting in keeping it in proper form. A continual motion is given to this bag in the following manner:—Over the fly, E, of the axis, C C, a triangular piece of iron, *w*, is fixed, which moves with the axis, and as this piece revolves, the angular points come in contact with the finger, *v*, moving it through an arc of from 40° to 45°. The finger being fixed to the cylinder, *t*, causes this also to move, and by its means the rod, *s*, and the bag, R, with which it is connected, are tremulously agitated. In this manner the finer parts of the flour are sifted through the bolter-cloth; while the coarser flour and bran pass off to the bin, T, or are received in the sieve, S, where the coarser parts of the flour are completely removed. A similar oscillating motion is given to the sieve by the wooden spring, *c c'*, and the spindle, Z, through which the conducting-rod, *d*, passes. The coarser parts are often returned to undergo a second grinding and sifting.

An ingenious machine for dividing the flour from the bran, and which is very generally used, separates several kinds, according to their state of division, at one operation. It is termed the "dressing machine," and consists of long, hollow cylinders of wire-gauze,

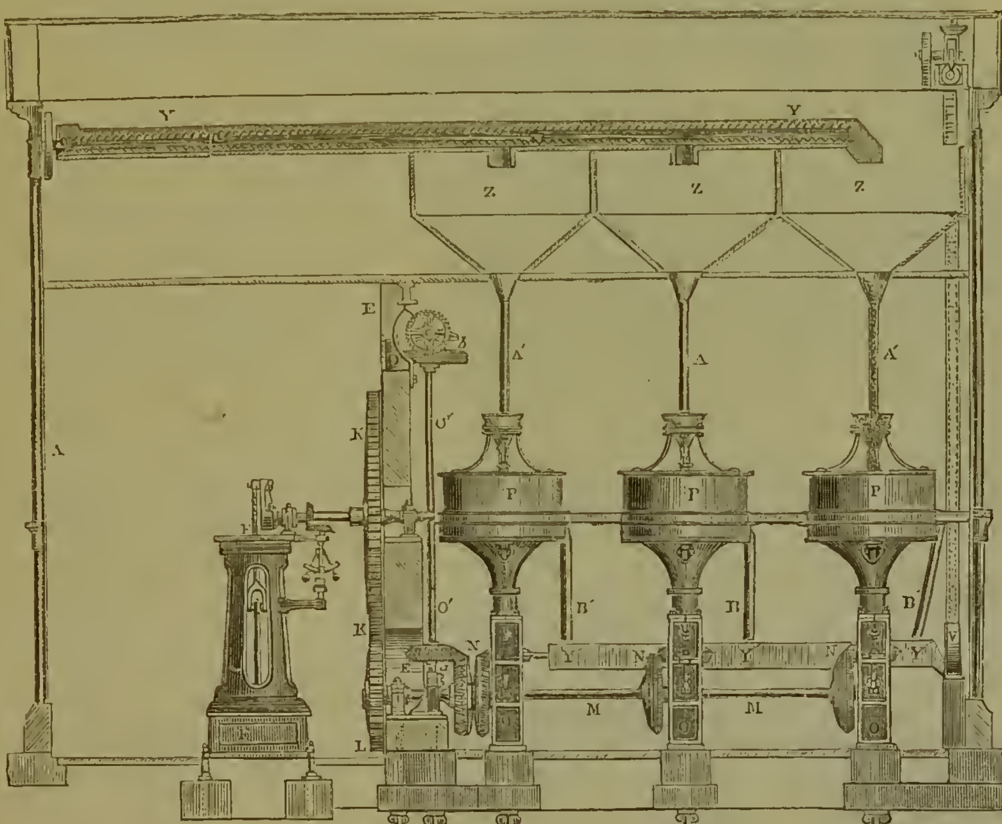
of various degrees of fineness, according to the qualities of flour to be produced, protected on the outside by a framework of longitudinal and circular slips of wood, put at regular distances from each other, the whole being fixed in an inclined position. In the interior a set of brushes revolves, rubbing against the wires, and clearing the meshes from adhering particles.

The entire machine is inclosed in a box, which prevents the escape of floury particles in the form of dust. The cylinders of wire-gauze are so fitted in as to be readily replaceable by others, of any requisite size, to suit the fineness of the flour to be separated.

After some time the meshes of the cylinders get filled with adhering particles of flour, and the brushes also lose much of their effect from the inclination of the bristles, occasioned by being worked in one direction; consequently, the dressing is very imperfectly accomplished. The first difficulty is overcome by means of a strong brush rubbed exteriorly against the wires from time to time; the adhering substance is by this means completely removed. The second fault is obviated by having the brushes so arranged that they can be made to move in either direction, by which they last a longer time and work much more effectually.

Fig. 10 represents the whole mill. E E is the masonry for supporting the driving gear of the machinery; F, the steam-engine; K K is the spur fly-wheel of the engine working into the pinion, L,

Fig. 10.



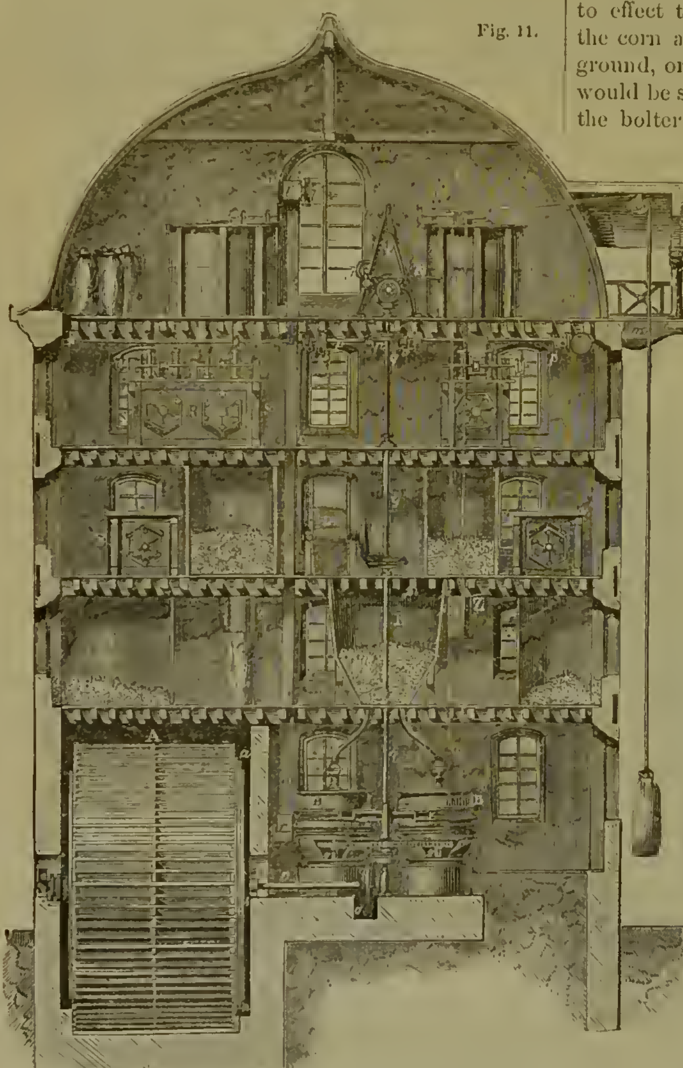
The main horizontal shaft of the mill is represented by M M, and the level mortise wheels and pinions for driving the stones are seen at N N N; P P P are the millstone cases. There is a passage conducting the grain from the elevator to Y Y, the "creeper," by which it is distributed into Z Z Z, the garners for feeding the stones. A′ A′ A′ are feeding pipes made of tin plate; B′ B′ B′, pipes by which the flour is withdrawn from the stone cases into Y′ Y′ Y′, the second creeper-box, which conducts it to the second elevator; C′ C′ is the shaft which works the dressing machine by the bevel wheels, *a* and *b*.

Fig. 11 is a sectional view of the interior arrangement of a French flour mill. The motive power is a water-wheel, A, and by means of a spur-wheel, *a*, appended to the axis and pinions, *b b*, this is made to move the stones, B B. Motion is likewise communicated to the cleansing machine, P, the bolters, R R, &c., by an upright shaft, *q′ q′ q′*. The corn is cleansed by a winnowing machine, L, before it descends to the hopper, K, from which the stones are supplied. An endless chain of buckets, O O O, raises the flour from the stones to the bolter, *p*, whence, after undergoing a purifying process, it descends to the several other machines, R R R, by which the various qualities of flour are separated and collected in sacks. The details of the arrangement are too numerous to be fully stated, but the

figure above given will be intelligible to every miller.

By the common methods the grain which is ground at one time must be passed through the stones repeatedly, their relative position being altered each time, according to the degree of fineness required. The stones, by continued use, become so much abraded that they would no longer touch the grain if the miller did not, from time to time, regulate their distance by a screw provided for the purpose.

Fig. 11.



During the first two or three courses of the corn between the stones the runner is so raised that the grain is only coarsely broken, and this is repeatedly passed through the grinding and dressing apparatus till no more flour is reduced ; the residue is bran.

Fine flour of various qualities is obtained from that portion of the grain which flies off as dust from the bolter, and the other parts remaining, already deprived of the bran, are designated by different names, according to their appearance and degree of fineness. In some of the London mills no less than seven different products are obtained, the relative quantities of which are the following :—

Fine flour,...............	5	bushels	3	pecks.
Seconds,......	0	"	2	"
Fine middlings,...........	0	"	1	"
Coarse middlings,........	0	"	0·5	"
Bran,.........	3	"	0	"
Twenty-penny,..........	3	"	0	"
Pollard,.................	2	"	0	"
	14	"	2·5	"

The grain is usually moistened before grinding, to effect the complete separation of the husk. As the corn appears in the market, it is too dry to be ground, or at least, if ground in this state, the husk would be so finely divided that it would pass through the bolter with the fine flour, and communicate a brownish colour, which would be very objectionable. To prevent this the grain is cast into a tank of water, the lighter impurities as they rise to the top being skimmed off. After draining the excess of water, another portion of dry grain is added to that which was moistened, and after the mixture has been left to soak for some time, it is submitted to the mill. Many millers merely sprinkle the grain with the water.

The flour, as it comes from the stones, is hot, on account of the great friction to which it is subjected, and if allowed to remain at the acquired temperature *en masse*, it would ultimately become acid, particularly if the grain contained much moisture.

In well-regulated mills this source of injury is neutralized by immediately conducting the ground material by means of an elevator to a spacious floor in the upper part of the building, where it is spread out to cool. This operation is the more needful when the grain is so dry that the husk cannot possibly be detached from the flour in the grinding, unless it be previously moistened.

In consequence of the moistening process, the finest quality of flour imported from America is often found agglutinated into hard musty lumps. MITSCHERLICH and KROCKER, who examined this subject, show that wheat in which sugar was proved to be absent before sending it to the mill, yielded after being ground as much as 4 per cent.; this transformation of the starch into sugar could not be produced otherwise than through the internal action of the gluten, aided by air and superabundant moisture. When once the action sets in, it quickly passes through the whole heap, if not speedily checked either by cooling or drying the floor. The decomposed starch or sugar, when the mass is left to cool gradually in large heaps, soon enters upon the alcoholic, and sometimes even the acetous fermentation. This action always takes place in the

middle of the heap first, and proceeds towards the surface. The affected flour has a gritty feel, not unlike that of gypsum, and, of course, makes very unwholesome bread.

Flour containing only its natural portion of moisture is the best for stock and exportation. BERGS kept various samples of flour, and found that the second and third qualities, which contained most gluten, were completely spoiled after keeping only nine months, during which no want of care could be alleged as the cause, as the casks were placed in a cool, airy, and dry warehouse.

Many English millers are much opposed to moistening the grain previous to grinding it, and even dry damp grain upon a kiln to deprive it of an accidentally acquired humidity; the flour which they obtain, though inferior in colour to other varieties, is better adapted for storing and exportation than any other. The American flour is decidedly the whitest brought into the market; this must be owing to their more perfect sifting machinery, and cannot be from the better quality of their grain, as it is universally allowed that English wheat is seldom or never surpassed. The Americans also cool their flour very rapidly by means of special machinery, while the English miller leaves it to cool in the sack.

The best way of securing a flour of the whiteness of the American article, and possessing at the same time the durability of the English, would be to grind the grain slightly moistened (as is the custom with the American millers), and afterwards to dry the flour in properly constructed chambers; the excess of moisture would in this way be expelled, and the husk or bran would be more completely detached from the flour. This method has been tried on flour for shipment with very favourable results.

On the whole, English millers obtain a larger bulk of flour than the Americans. Bran, as it comes from English mills, only slightly whitens a black cloth, whereas American bran retains considerable portions of the matter of the grain attached to it.

The following are data given by KNAPP, showing the proportionate results obtained from the old and new mills; and as this chemist states them to be the mean of six experiments, they may be looked upon as a fair comparison of their merits.

From 100 lbs. of maize were produced in an old mill—

Fine flour,	55 pounds.
Middle flour,	18 "
Black flour,	9 "
Bran,	18 "
	100

And from the same weight of barley the proportions were—

Fine flour,	40 pounds.
Coarse flour,	20 "
Middle flour,	10 "
Black flour,	5 "
Bran and loss,	25 "
	100

In a new mill at St. Maur, near Paris, there were obtained from every 100 parts of grain—

72 of flour, first quality,
3 of flour, second quality,
3 of flour, third quality,
7 of coarse bran,
10 of fine bran,
3 of black bran meal,
1 separated by sieves,
1 loss.
—
100

Dr. HASSALL gives the following table as the yield of a quarter of wheat—weighing 504 pounds—when ground:—

	Pounds.
Flour,	392
Biscuit, or fine middlings,	10
Toppings, or specks,	8
Best pollard, Turkey pollard, or twenty,	15
Fine pollard,	18
Bran and coarse pollard,	50
Loss sustained by waste in grinding, &c.,	11
	504

BREAD MAKING.—If flour is worked up with water, and dried either spontaneously or at a very low heat, a substance is obtained which binds together with no great degree of firmness; the starch and other matters remain in such a mass unaltered; it is insipid and indigestible. But if the mass be heated throughout for some time at a temperature of 212° Fahr. (100° C.) a change occurs; the starch is rendered soluble, and the whole body becomes firm, dense, and compact. Such was in ancient times the bread making process universally practised; even still, in many parts of the world, this method of baking is continued, as in the North of India and Afghanistan: the Jews also make their Pascal or unleavened bread in this way; and in preparing sea-biscuit this method continues, with only slight modifications, to be generally adopted.

Bread prepared in this manner is merely the dough dried in a peculiar way, with the formation of an outward crust, and the thinner the cakes are made the more easily is this effected. The density of such bread is much greater than that of fermented bread, and in consequence of all moisture being expelled, and the constituents of the flour being only very slightly different from their original composition, it is difficult to masticate; it keeps, however, a much longer time than any other kind, and on this account is admirably adapted for sea stores.

A most necessary quality in bread is, that it should be furnished with a thin crust, and have sufficient porosity to present a large surface to the action of the gastric juice; and to insure these qualities various means are adopted. Fatty and oleaginous matters are used to distend the plastic mass, which they effect as in the formation of pie-crust.

Leaven, another of the bodies used to give bread a great degree of porosity, is a portion of the ordinary dough left in a warm situation till fermentation sets in; if left too long under this influence, however, it becomes first sour and then putrid. The use of leaven in baking is to induce the same fermentative action in the fresh dough which is going on in itself;

but it should be employed with the greatest caution, for if the acid transformation has commenced in the leaven, it will communicate a disagreeable taste to the bread.

Yeast is now almost universally used in place of leaven, and has considerable advantages over it, since it confers porosity in a high degree, without generating any disadvantageous property in the loaf.

The principal materials requisite for obtaining good bread are flour or meal, yeast or leaven, and water, with a suitable quantity of salt; various other matters may be added to confer greater whiteness and richness on the loaf.

FERMENTATION.—Panary fermentation, induced by yeast or leaven, is the same as that which takes place in the formation of alcohol, though the action is more limited. It has been shown that sugar is not a constituent of grain, more especially of wheat; though, when the latter is exposed to moisture, this substance is formed in considerable quantities. When the flour is mixed with a proportion of water sufficient to form the dough, the production of sugar becomes more brisk, for the gluten of the flour induces its formation, and the ferment, whether it be leaven or yeast, effects the conversion of this sugar into alcohol and carbonic acid gas to a greater or less degree. All the sugar which the gluten of the flour would be available in producing is not, however, formed in the dough; but the amount is proportionate to the time the flour is left in contact with the water and ferment, before its introduction into the oven.

The formation of a lump of dough by the use of a ferment and water will readily demonstrate that not only is a considerable surface exposed to the air, but a volume is also enveloped in the mass; and, as has been shown under ACETIC ACID, alcohol in contact with air or oxygen, at a slightly elevated temperature, readily passes into vinegar; so, in this case, the decomposition of the spirit follows, if fermentation be prolonged beyond the necessary period.

The retention of the carbonic acid and alcohol is the cause of that sponginess which is so desirable in bread; but it will be seen that some portions of the valuable constituents of the flour are destroyed to give existence to them, and so far as the vesicular structure of the dough is concerned, their action is merely mechanical.

Various compounds setting free carbonic acid have been tried as substitutes for yeast, but their use is always attended with indifferent success. The reason is evident. When such substances are decomposed to give the carbonic acid, the action takes place so rapidly that the baker has not time to work his dough as usual, and still retain the gas; and even during the short time which he requires to form the loaf, a considerable portion of the elastic fluid is evolved to his loss. It appears, also, that the loaves made by such treatment are full of large cavities, with interposed walls of doughy consistence, unlike bread fermented with yeast, which is so regularly cellular through its entire extent, arising from the carbonic acid and spirit being generated in all parts of the mass of dough.

It is a remarkable fact, that a little soap-suds added to the dough arrests fermentation; its action depends upon the absorption of the carbonic acid by the alkali of the soap, forming a carbonate, and the fatty acid of the soap is liberated: both these are anti-ferments, but besides their arresting the fermentation, the bread is rendered dense by the absorption of the carbonic acid already formed. Yeast possesses a very disagreeable bitter taste before it is mixed with the flour, but when the loaf is baked no such taste can be detected.

FOWNES has shown that flour and water mixed, and left at the normal temperature of a moderately warm room, arrives at the usual state necessary to induce fermentation in malt wort, only after a period of six or eight days; during this time the mixture contracts a bad odour and an acid reaction. The conclusion from this fact is, that dough should be left to the action of the ferment only so long as is necessary to generate sufficient carbonic acid gas to give the loaf its proper size.

Greater difficulties are encountered with leaven than when yeast is used; for, as has already been mentioned, leaven is merely a portion of the dough in a state of fermentation, reserved for the next operation, to induce similar action in fresh portions of flour to that which it undergoes itself, and this it effects in a manner similar to that of fermenting worts with a fresh infusion of malt, as fermenting grape juice reacts upon a fresh extract of the fruit, or as yeast serves the same purpose.

During the action of the leaven other compounds, such as lactic acid and complex nitrogenous substances, arising from the decomposition of the plastic bodies of the flour, are formed; and when the leaven is added to the dough in this stage of decomposition, it gives rise to like compounds, and the result is that such bread speedily turns rancid, and consequently is unfit for use.

Persons with weak digestive organs are unable to use bread made in this way—"black bread."

The fermentation of dough, if allowed to proceed, ends in putrefactive decomposition; and if the fermenting dough has entered into this phase, it tends to induce the same change in the fresh paste, without any intermediate modifications of the fermentation being observed. The state of the leaven must therefore be carefully noticed before using it.

Yeast is easily retained in good condition by mixture with sugar, but leaven demands more care. In Germany, where leaven is used to a large extent, the baker mixes a quantity of it with a portion of the flour and water intended for the next baking; as soon as the fermentation has raised this first addition, a larger portion of the flour is added, in the same way as before, the whole left again to ferment, and so on each time, till about one-half of the flour is in a state of fermentation. This procedure is called by the Germans *Anfrischen*, and its object is to supply sugar so as to maintain the vinous fermentation. The quantity of ferment or leaven required when used thus is very small in comparison to what would be necessary if the whole of the flour was added at

once; and the retention by the dough of the alcohol and carbonic acid developed throughout the fermentation produces a uniformly raised loaf.

Various sorts of bread are obtained from the several kinds of flour. Wheaten bread, or "firsts," is made of the finest flour; household bread, or "seconds," is made of somewhat coarser flour; brown bread, or "thirds," is made from an admixture of two or more kinds of flour remaining after the firsts and seconds flour have been taken away; and "composition bread" is made of ground but undressed wheat.

The yield of bread is generally about 90 quartern loaves per sack of 280 lbs. of flour. If the flour, however, be of the best quality, more water is retained, and a greater weight of bread results. When the dough is made of the proper consistency, the usual loss by baking amounts to about one-tenth of the weight of the mass of dough, or one ounce and a half to the pound.

BAKING APPARATUS.—The ordinary apparatus and other requisite furniture for common purposes, are comprised in the following:—On one side of the room a large dresser is erected, and over it a range of shelves. The kneading-trough occupies the opposite side of the room; it is generally from 6 to 9 feet in length, 3 in height, about $2\frac{1}{2}$ in breadth at the top, and tapering to the bottom, where it measures only about a foot and a half. A sliding or sluice-board is furnished in the interior, and a lid covers the whole. At one end of the room is a boiler, holding from 15 to 30 gallons of water, and at the other end the oven.

The other utensils of the bakehouse are the "seasoning tun;" the "seasoning sieve," made of hair, tinned sheet-iron pierced with holes, or perforated zinc; wire sieves, for sifting the flour; a salt bin; yeast tub; a bucket; a spade or shovel; a bowl; scales and weights; and a large dough knife; a scraper, for cleaning the dough off the trough and moulding board; four or five short shovels of various sizes, attached to long handles, and called "peels," which are used to put the loaves in, and also to take them from, the oven; tin or iron plates; cloths for covering the dough and bread; a "scuttle" or "swabber" for cleaning the oven preparatory to setting in a batch of bread; supports, made of rectangular pieces of beech, fixed round the sides of the oven for the purpose of keeping the loaves in their places; the "rooker," a tool in the form of the letter L, for the purpose of drawing out the ashes from the oven; a hoe, used for a similar purpose; and a rasp for detaching any burned parts from the baked loaf.

The baker first of all starts his ferment with potatoes. To do this he boils, peels, and mashes 5 to 6 lbs. of potatoes for each sack of flour used, and adds to these $1\frac{1}{2}$ gallons of water, 2 to 3 lbs. of flour, and 1 quart of yeast. The whole is then stirred till it becomes a smooth paste. Fermentation speedily sets in, and in about three hours will have come to a head, when the dough may be made.

To do this the baker takes about 2 gallons of water at a temperature varying from 70° to 100° Fahr. (21°·1 to 37°·7 C.), and adds the yeast prepared as above, and enough flour to make a stiff dough. The amount of water employed varies considerably with the quality of the flour, being from 40 to 60 or 70 per cent. of the flour. As a rule, the bakers use equal weights of water and flour.

Good flour always requires more water than inferior, to bring it to the consistence necessary for the retention of the volatile compounds which will be subsequently developed; the starch and gluten in good flour being in a more minute state of division, and therefore more retentive of water.

Having mixed the water, yeast, and flour, as above, proportionably, to give the mixture a thick ropy consistence, the mass is permitted to rest for some time; a proper quantity of salt is next added, and the whole covered up in a small kneading trough in a warm situation. This mass is called the "sponge," and the placing of it in a warm situation is termed "setting the sponge," being in effect the inducement of the vinous fermentation in the sugar of the flour, signs of which appear in about an hour afterwards, by the mass becoming inflated from carbonic acid gas arising out of the decomposition of the sugar into alcohol. If the sponge be too thin the bubbles of carbonic acid rise quickly to the surface, break, and are lost, leaving it almost in its original state; but when it is of moderate consistence, the tenaciousness of the mass retards the evolution of the carbonic acid till it accumulates in large quantities, which distend the sponge until it can no longer retain it. The escape of the gas causes the dough to collapse; and as a further quantity of gas is produced by the progressing action of the ferment, the dough rises as before, till it acquires twice its original bulk, when it again falls. Were this operation of the sponge suffered to continue, it would last for a considerable time; but in that case much of the valuable constituents of the flour would be destroyed, and the prolonged action would convert the alcohol into acetic acid and spoil the bread.

After the first rising, if the baker judges that fermentation has pervaded the whole mass, the baker "breaks the sponge" by adding the remaining quantity of flour, water, and salt (in the proportion of $2\frac{1}{2}$ to $3\frac{3}{4}$ lbs. per sack—new flour requires the latter quantity to make the dough to "bind"), and incorporates the whole material thoroughly by "kneading." But if he thinks that the operation is partial, he delays adding the second part of the flour till the second rising; this he calls "taking a second fall."

The kneading is continued till the fermenting sponge becomes completely incorporated with the flour recently added; for without this precaution the cellular texture of the loaf would not be attained, and the fresh flour would be left in doughy concretions in the mass. Hence the kneading forms a material part of the baker's work, and should always be well executed, as no loaf is properly made unless it has been thoroughly wrought up. By this mechanical operation, the glutinous parts of the flour are

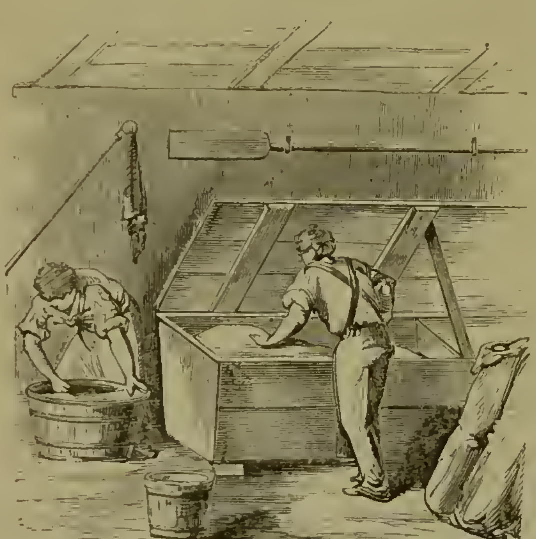
rendered so elastic that the mass of dough which is made is capable of expanding to twice or three times its volume without cracking. The criterion by which the baker judges when the dough is properly blended is by indenting it, and if it does not adhere to the hand on its withdrawal, he considers that the dough is properly worked.

Fig. 12 represents the kneading trough.

After the first operation, the dough is covered up with a flannel cloth and left at rest for a few hours, during which time it is in active fermentation and swells considerably. A second kneading is then given, with the view of equalizing the carbonic acid formed in the mass during the time the dough remained at rest, and preventing portions of the bread from being "sad;" it is, therefore, less laborious than the other kneading.

The dough prepared in this way is then weighed out into lumps of the requisite size; these are next shaped into loaves, or put into tins, as the case may

Fig. 12.



be, and set aside in a warm place till they have acquired about twice their bulk, partly from the generation of fresh carbonic acid, and partly from the expansion of that previously formed. The oven being prepared, the loaves, properly shaped and weighed, are introduced and allowed to remain till baked, after which they are drawn out with the peels, being now no less than double the size they were before baking.

It is absolutely necessary that the proper volume of carbonic acid should be generated in the dough before it is put into the oven, as the strong heat immediately arrests further fermentation, and the swelling of the loaf arises from the expansion of the bubbles already formed throughout the mass, which gives to it the light porous texture peculiar to good bread. Each of these cellular spaces is bound by a kind of integument, and the whole are so arranged that they form a succession of layers one above the other, and at right angles to the crust. When the loaf consists of an aggregation of the layers it is called by the baker "piled bread." Dr. Colquhoun contrasts the virtue of piled bread with the unpiled by noting that, if the former be pressed in the hand, it will crumble, and if thrown into hot water it will intumesce, disintegrate, and admit of being easily diffused; whereas the unpiled bread, when treated similarly, yields a solid cohesive body, and hot water reacts upon it no further than to soften it into a permanently tough mass.

The oven, previous to the moulding of the loaves, is thoroughly cleaned out with the swab, and the "upsets" or supports chalked, to prevent the loaves adhering to them. The various kinds of loaves are placed in the oven in connection as closely as possible, but the cottage loaves, rasps, &c., must be left some short distance apart, that they may be entirely crusted. Much manual skill is requisite in introducing the bread into the oven; when this is accomplished the whole is retained in its place by a set-up placed in front, the door is next closed, and left so from an hour and a half to three hours, according to the size of the loaves, excepting when it is occasionally opened to view the progress of the baking.

Many bakers use 12 lbs. or more of potatoes to 2 quarts of brewer's yeast, and this quantity is added to every sack of 240 lbs. of flour.

The yeast used by bakers is obtained from the ale breweries. Porter yeast will not answer, as it communicates a disagreeable taste to the loaf. Ale yeast is the best and strongest, and is most extensively used in bread-making. Small-beer yeast is said to be weak and rapid in its effects; it is sometimes used in making rolls. Yeast is of a fawn or light-brown colour, and of a frothy consistence; when newly made it is in brisk action, and bubbles of gas escape from it.

"German barm" is a form of yeast which is much used. It is a paste-like substance, and is sometimes called "dried yeast," and consists of sporules only, with but little adherent moisture and no gas. It is merely yeast precipitated from a fermenting liquid, filtered off, and dried at a proper temperature. The following is the mode of preparing it:—Crushed rye is mashed with a certain quantity of barley malt, and the wort cooled to the proper temperature. Half a pound of carbonate of soda and 6 ounces of sulphuric acid, diluted with their weight of water, are proportioned to every 100 lbs. of the crushed grain employed and mixed with the wort, and fermentation induced by the addition of yeast. From the strongly-fermenting liquid the yeast is skimmed off and strained through a hair sieve into cold water, into which it is allowed to settle. It is afterwards washed with one or two waters, and finally pressed in cloth bags till it has the consistence of dough. Its smell is pleasant and fruity, and it will keep in a cool place for two or three weeks. After this it passes into a putrefying decomposition, acquires the odour of decaying cheese, and, like it, possesses the property of changing sugar into lactic acid, instead of into alcohol as before. 100 lbs. of crushed grain will

yield 6 to 8 lbs. of the pressed yeast. It is made in large quantities at Rotterdam, and is imported to this country through Hull.

The utmost care is necessary to be observed in its preparation, as it is very readily spoiled; its vitality is destroyed even by slight mechanical injuries, by too high or too low a temperature, and also by chemical reagents. It is put up in Germany in hempen bags, each containing about half a hundredweight; when exported in casks, it has been known to burst them from evolution of carbonic acid. It should be carefully handled, as a slight concussion with another body injures it; even when packed, it is equally liable to be spoiled, as if the bag, in being removed, falls, so as to receive a shock, it is "killed," and scarcely any of its valuable properties as a ferment remain. HASSALL states that yeast which has been thus injured darkens in colour (somewhat like the change which an apple or pear undergoes when it putrefies), and, from being crumbly, becomes soft and glutinous, adheres to the fingers like flour-paste, and sometimes emits a fetid, disagreeable odour.

The injured and uninjured German yeast submitted to a microscopic examination, exhibit no difference in their appearance.

"Patent yeast" is an infusion of malt and hops, the latter being intended to diminish the propensity of the solution to acidify. It is a thin aqueous liquid, through which numerous sporules of the yeast plant are disseminated. Many bakers, in preparing patent yeast, likewise add either common yeast or German barm, with an infusion of flour or potatoes, their object being to make the product more effectual, as these substances supply, in greater abundance, the nourishment of the yeast cells; and contain more material for the generation of carbonic acid.

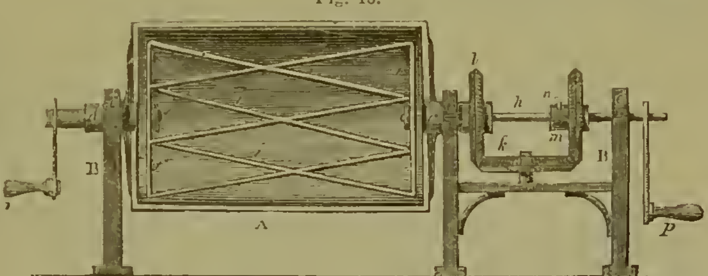
An improvement in bread-making which has been effected of late, is in the kneading of the dough. In extensive bakeries, the trouble of mixing the flour, yeast, and other ingredients, is so great that manual labour could not accomplish it; hence machines have been constructed to serve the same purpose.

There are a great variety of such contrivances, but that of CLAYTON may be taken as typical. In point of fact any "pug-mill," horizontally arranged, would serve the purpose equally well. CLAYTON's consists of a rotatory drum or barrel, mounted on gearing, with a hollow axle, and an interior frame of cast iron caused to revolve by a solid axle, which passes through the hollow one. The revolving drum and frame are made to turn in contrary directions, so that the dough is turned over at each time the wheel revolves, and the knives, or diagonal cutters, which are fixed in the frame, tear the mass asunder, and again reunite it, till the whole of the ingredients are completely incorporated.

Fig. 13 is an elevated section of the apparatus. A is the barrel or drum into which the several ingredients for the formation of the dough are put; it is mounted on the framework, B B; *c d* are the hollow axles which turn on suitable bearings at *e e*; *f f* is the revolving frame which is placed in the interior of the barrel, A, and mounted on the solid-axles, *g h*. The ends of the interior revolving frame are braced together by the parallel slanting spars, *i i i*, which act with great effect in blending the dough, as the case is put in motion. Either the barrel may be made to revolve without the frame, or the frame can be put in motion, leaving the barrel stationary; or, if necessary, action can be communicated to both. The gear work and winches, at each end of the machine, are the means by which the operation is performed. When it is requisite to put the barrel and interior cylinder in motion in opposite directions, the hollow cylinder of the wheel, *m*, is screwed tightly to the axle, *h*, of the interior revolving machine, by the screw, *n*, and by turning the winch, *o*, it will be found that both these motions will be given to the machine.

The interior cylinder, *f f*, may be worked by unscrewing *n*, and turning the winch as before; for the axle, *h*, does not communicate with the wheel, *m*, except by the screw, *n*. Again, if the rotatory action of the barrel be wanted, leaving the other stationary, it may be obtained by turning the handle, *p*, which,

Fig. 13.



however, gives motion to the wheels at the opposite end, but this has no power to act upon the inner cylinder, if the screw, *n*, be disconnected.

A kneading machine used in some of the French bakehouses is represented in Figs. 14 and 15, the first being a longitudinal section, the line of division passing through the axis, and the other a front elevation. P P, the frame of the machine, is made of wood, and divided into three compartments for the reception of the dough. The wooden bars, *o o o*, are placed in the interior of the chambers, so as to divide the dough whenever the cylinder revolves. One portion, D, may be opened and laid over upon the other by means of a hinge and movable joint when the dough and flour are introduced. Of A, B, and C, the three divisions of the machine, two—B and C—are reserved for making the dough, the other being used in preparing the sponge. *a* is a pulley which receives its motion from the engine, and transmits it to the cylinder by the pinion, *b*, and the spur-wheel, *c*; *d* is the fly-wheel to regulate the motion of the machinery; *g* is a break to act upon the fly, *d*, by means of a lever, *h*; and *i*, the pillar of the fly-wheel.

The compartments of the machine are furnished

at pleasure with cross-bars, which serve to draw out the dough.

When operations are continuous, the sponge is constantly being prepared from a mixture of—

275 pounds of ordinary leaven,
148 pounds of flour, and
76 pounds of water, making a total of

499 pounds.

When the kneader has been at work for seven minutes the cylinder is opened, and after verifying the state of the leaven—adding water if it be too stiff, or flour if the reverse be the case—the lid is once more closed, and the machine again put in motion. In ten minutes afterwards the kneading is completed. As much sponge is obtained from the two kneading compartments, containing about 500 lbs. of dough, as keeps two ovens at work alternately.

Fig. 14.

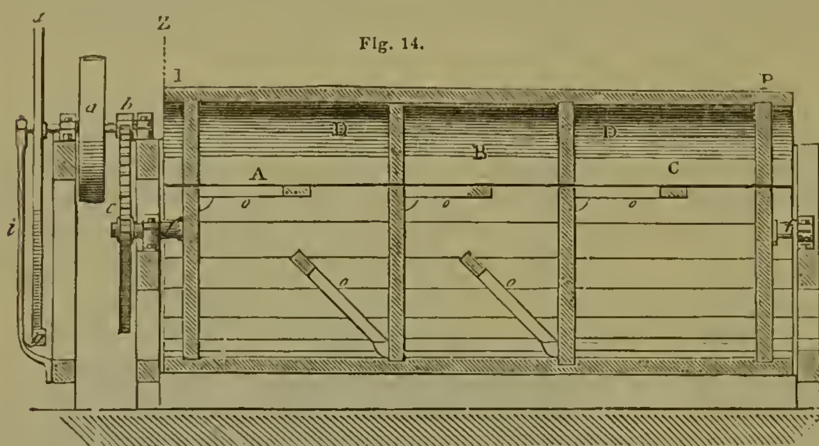
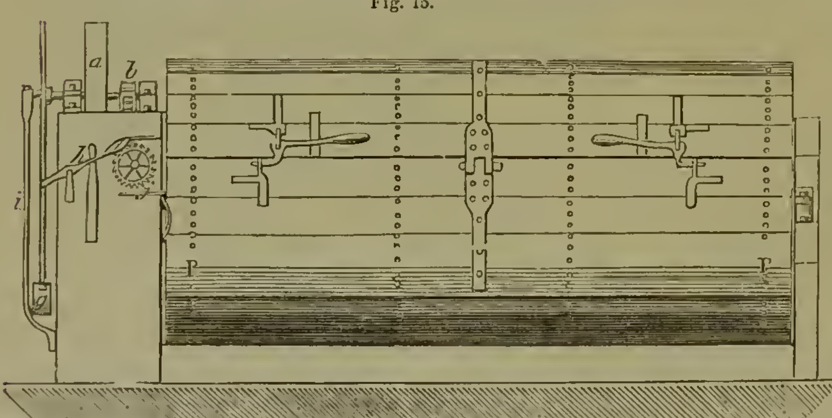


Fig. 15.



For this purpose, 165 lbs. of the dough are taken out of each of the compartments, B and C, making in the whole 330 lbs.; to this quantity about 200 lbs. of flour, and 100 lbs. of water—about 10 gallons—are added; the united weight of which is about 630 lbs. The two compartments are again replenished with the original quantities of flour and water, to make up the mixture, as before stated; namely, 100 lbs. of flour, and about 50 of water, and the cylinder set working as before.

The same means which work the leaven in the compartment, A, suffice to make the paste or dough in the division, B. On opening the cover, any portions adhering to the sides or cross bars are scraped off, and the whole removed, after which a similar quantity of flour and water is introduced to prepare a second batch for the next oven. The water is generally raised to a temperature of from 77° to 86° Fahr. (25° to 30° C.) in cold weather, and about 68° Fahr. (20° C.) in summer. At each addition of water, from half to three-quarters of a pound of fresh dried yeast is distributed through it. While this fresh quantity is kneading, the paste already produced is turned out upon the table and moulded into shape, or oblong form. All the lots of dough of the size of one kilogramme—$2\frac{1}{4}$ lbs. nearly—called cleft loaves, are placed upon a cloth stretched over a board, a fold of which is raised between every two loaves. The cloth thus laden with from ten to fifteen loaves, is transferred to the wooden shelves in front of the oven. While under the influence of the moderate temperature in this antechamber, or *fournil*, the loaves rise well and easily, and after they have attained the proper size they are transferred to the oven, an operation termed *enfournement;* it is performed by putting each loaf on a wooden shovel dusted with coarse flour, and placing it on the sole of the oven, all being closely packed, but disconnected with each other. A long gas burner introduced into the oven enables the workmen to view every part of it and place the loaves in proper position.

THE OVEN.—Until of late, very little improvement has been effected in ovens, and those in use at present in many provincial towns resemble, even in minute details, that discovered in the excavations of Pompeii.

Figs. 16 and 17 are a ground plan and an elevated section of the oven in general use in most countries. The space, A, wherein the bread is baked, is of an oval shape, and the usual dimensions are 12 feet by 10. The bed may be made of clay, but firebricks or tiles are better, and in this country it is mostly constructed of such material. In many parts of the Continent the beds of the ovens are formed of hewn *tuff* stone. The arch which covers the bed is low, being at most only about $1\frac{1}{2}$ foot in height, and the

entrance door, B, is from 1½ to 2½ feet broad; through this opening, both the fuel which heats the oven and the bread to be baked are introduced. At the back of the oven, three flues, *a a a*, are situated, and these come in a horizontal direction to the front of the oven, where they unite before entering the chimney, D. The smoke from the fuel is carried off through these flues, the draught of which is partly shut off by means of the damper, *b*. C is the space where the charcoal which is made in the oven is kept, and the pit, *c*, is provided to bring the workman on a convenient level with the door, to enable him to deposit the bread in the oven. E is the bakehouse, which is retained at the proper temperature for raising the dough by the superabundant heat from the oven and flues. The fuel in the oven is kindled by introducing a piece of lighted firewood through a small aperture in the door. As the draught of the oven is never very strong, the fuel often employed to heat it is thin boards, or brushwood, which readily ignites, as by the use of large logs the oven would not be heated properly. All the heat is derived from the flame from the wood; as soon as the charcoal begins to glow it is abstracted, and the bed of the oven prepared for

Fig. 16.

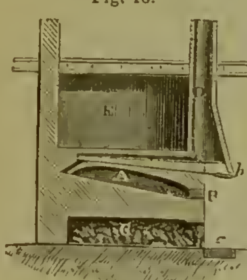
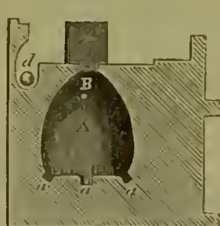


Fig. 17.



the reception of the bread. In many ovens which are not of large dimensions, and which are fed with very thin wood, the anterior flues are not supplied, but two small apertures rising in the arch at the front answer the purpose, and sufficient air enters by the door. Much heat is lost by this mode, but the loss is partly covered by the charcoal produced. In many villages turf is used, and is found to answer better than wood.

It is well known that the back part of the oven is warmer than the front, therefore to insure an even temperature the glowing coals are kept for some time near the door of the oven, to raise this part to a higher degree of heat. An hour's heating is always sufficient to bring the oven to a proper temperatnre, and sometimes half an hour will serve the purpose; the quantity of fuel is also continuously decreased, till a constant temperature is attained. The fuel being consumed and the charcoal withdrawn, the bottom of the oven is thoroughly cleansed out with a brush and moist cloth or swab. The heat of the oven is next proved by casting in a small portion of flour; if this assumes only a brownish colour, the proper degree is said to be attained, but if it should be charred, the introduction of the bread is delayed till the proper temperature is reached. The workman now introduces the bread, by placing two or three of the prepared loaves which had been hitherto left to rise, and are found considerably enlarged, each time upon the peel, the latter being slightly dusted over with a little bran, or refuse flour, to prevent the adherence of the dough; a lamp or gas light being placed beside the door and within the oven to illuminate the hearth, so that he can conveniently arrange each loaf in its proper position. When the whole of the batch has been introduced, the door is closed and made air-tight by a little cement or plaster. In the course of from twenty minutes to half an hour the batch is examined, and, if requisite, some of the loaves from the further end are changed to the front and colder part of the oven, those from the front being put to the back, after which the door is again closed and sealed till the bread is baked. The time required in this operation is dependent upon the construction of the oven, as also upon the size of the loaves; but it generally extends from one and a half to two or two and a half hours. Heat is derived during the baking from the hearth and elliptical arch of the oven; the former yields it by contact, and the latter by radiation. When the baked bread is withdrawn, the oven still remains very hot, but is incapable of baking another batch; it must, therefore, be heated with a further portion of fuel, to bring it to the proper temperature; the quantity required, however, is considerably less than what was used in the first instance. In the London bakehouses there is some slight alteration in the form of the oven, owing to coals being used instead of wood, but the principle of construction remains the same.

Of late years ovens continuously heated have been constructed. In Germany, one of considerable repute is erected at the military bakehouse in Hanover. This oven is heated by two furnaces; the bed of the oven is supported by numerous pillars erected upon the foundation, and the flues recede beneath it from the fire, and return along the arch at the top to the chimney; portions of the flame pass off laterally, and meet over the head, that the heat applied at the neck of the oven may be equalized with the hinder part. This oven is capable of baking, at each operation, 300 loaves of 7 lbs. each, or 2100 lbs. of bread; the fuel consumed being only 6·4 cubit feet of coal.

In Paris, famed for the beauty and quality of its bread, the model bakehouse of Mouchot is upon a similar principle. The kneading cylinders used at this establishment have been already referred to, and now the general arrangement and its other appendages will be considered.

Fig. 18 is a ground plan of the bakehouse, the upper part of the building being laid out as a granary, whence the flour is let down to the bakery as required. In this figure, *b b* are the baking ovens; *c* is the kneading apparatus; *d*, the space for the lift for raising the bread into a store-room in the upper part of the building; *e*, a space common to the two ovens, and into which the hot air passes; *f*, the wheel

which gives motion to the machinery for making the dough.

Figs. 19 and 20 are elevated sections on the line, x—x.

This oven is called by the French *four aérotherme*. The corresponding parts are indicated in the following figures by the same letters. A is the fire-grate whereon the fuel, which may be pit coal or coke, is consumed, and *j* the ash-pit; this fire is surmounted by an arch, and the flame and heated air ascend by two spaces, *c*—Fig. 20—and pass under the hearth or bed of the oven, F F, in the channels, E E. B B are chambers at each side of the grate, wherein the air is heated without coming in contact with the fire. From these reservoirs the warm air enters the oven by two apertures, one of which opens directly into it, while the other communicates with the flues, so that the air may be more highly heated by coming in contact with the products of the combustion, and which are carried off through those spaces. The sole or bed of the oven is at first heated with dry wood, as the ordinary ovens, but when once the proper temperature is attained, it is kept up by the warm air which is admitted into the oven in the manner described, and by the hot air which is always passing along the flues, E E, beneath it. During the baking, the air which enters the oven becomes saturated with moisture, and in this state passes off at the top, by an opening which connects it with the reservoir, B, from whence it returns as before through *a a*, as long as the oven is at work. D is the chimney, and G G is an inclosed space to act as an insulator to the oven, and which is used to heat the dough previous to its being placed in the oven.

Fig. 18.

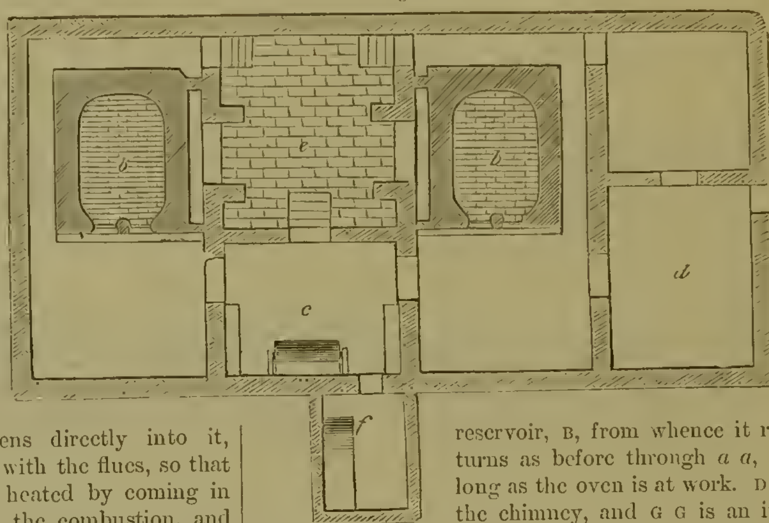
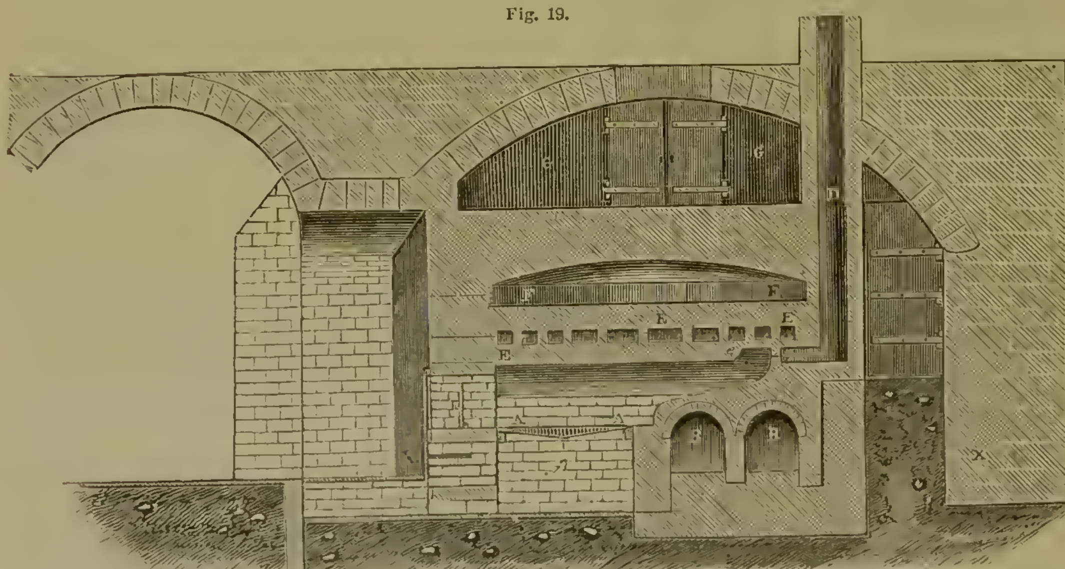


Fig. 21 is a front view of the oven, showing the

Fig. 19.



doors at *p p*. When the oven is charged and the two doors shut, the two registers are thrust in to avoid firing the dough too much. But as soon as the temperature falls from 572° to 554° Fahr. (300° to 298°·8 C.), the registers are opened, to bring up the temperature to what it was at first, by permitting the circulation of warm air, which comes into the interior of the oven from the cavities below, situated round the furnace.

If the temperature has been sustained at about 572° Fahr. (300° C.), which is easily managed by inspecting the exterior tube of a thermometer fixed with its bulb in the interior, 300 kilogrammes of dough, divided into 1 kilogramme loaves, will be fired in twenty-seven minutes. The charging of the oven having occupied ten minutes, and the clearing about the same period, each baking, therefore, occupies a period of forty-seven minutes.

On reviewing what has been already said, it will

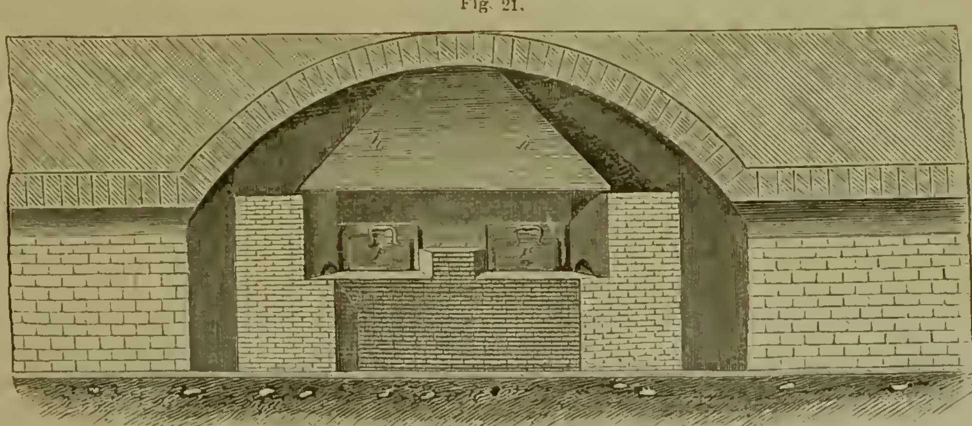
be seen how much better adapted wheat flour is for the preparation of bread, than that of the other cereals. When flour from barley, oats, or rye, is made into a dough and fermented, the carbonic acid is, owing to its want of tenacity, not retained as in the dough from wheat flour; hence, when a dough made of any other flour than wheat is fermented and baked in the usual way, the bread produced, besides being inferior in colour, is dense and only very imperfectly "piled."

A marked difference is to be observed between the exterior part of a well-baked loaf and its interior; the former is of a light-brown colour, hard and thick; while the latter is soft, white, elastic, and interspersed with numerous cells: these differences are brought about by the chemical action of the heat applied in the oven, but in what manner has never been fully ascertained.

Fig. 20.

REICHENBACH attributes the brown colour of the crust to the presence of a peculiar body which he calls "assamar," from *assare*, "to roast," and *amarus*, "bitter." He prepares it by toasting thin slices of bread, treating the powdered toast with alcohol, and evaporating to a syrup, and repeating this treatment till he obtains a residue soluble in alcohol; the assamar is then precipitated from this solution by ether. The same body is produced when meat, sugar, gum, starch, and other substances are roasted.

Fig. 21.



Starch can be readily detected in any part of a loaf; on moistening it with a solution of iodine a blue colour quickly makes its appearance. By macerating the bread with water, and acting upon the extract with a little diastase or malt extract, the starch, which was at first easily detected, will in a short time be no longer detected by the most delicate tests.

The crumb of bread is regarded by KNAPP as merely an intimate mixture of starch paste with gluten, the separation of which may be effected by washing with water in the usual way for removing the starch from the crude gluten.

UNFERMENTED BREAD.—Two varieties of this kind of bread are to be met with. One consists of merely flour and water, with a little salt as a seasoning. Wheat flour thus treated is always

made into biscuits. Rye, oat, or barley flour is thus invariably used, as their want of gluten excludes them from being used for making ordinary bread. The flour of these cereals is often mixed with wheat flour in biscuit factories; it cannot be used alone, as the dough is not sufficiently elastic to be extended into thin sheets.

The other variety of unfermented bread is made of wheat flour, and in loaves the same as those already described. As the raising of a loaf is merely a mechanical action of the carbonic acid and spirit, it occurred to some chemists, that if the carbonic acid could be supplied without causing a fermentation in the bread, the whole of the sugar might be retained, and the bread would be more nutritive.

Various means were resorted to to effect this result, such as kneading the flour with water saturated with carbonic acid, mixing bicarbonate of ammonium with the flour, &c. Dr. WHITING proposed, in 1837, to mix an alkaline carbonate with the flour, and to knead the mixture with water acidified with hydrochloric acid, in the exact proportion to convert the soda employed into chloride of sodium, while carbonic acid was disengaged to distend the dough.

Butter or other oleaginous matter, as also bicarbonate of sodium and tartaric acid (constituting the so called baking powders), are likewise in constant use for raising the dough; the former is used by confectioners for making pastry, and the latter, like the preceding mixture of carbonate of sodium and hydrochloric acid, for making loaves.

When butter is used, it is mixed with the dough, which is then rolled out into a thin sheet, and recoated with a thin layer of butter; after which the operator folds the sheet of dough outwardly from him; he next rolls it out as before, and lays on a second coating of butter, and proceeds as in the first instance, till the mass has been rolled and buttered eight or ten times. Some only butter the dough once or twice, and then repeatedly roll it in the same direction as above described.

When such a sheet is placed in the oven, the heat causes the disengagement of elastic vapour from the water, which finds free vent between the numerous layers of dough separated by the diffused fatty matter; these then swell up, thereby giving that peculiar puffy construction to the baked material, which is a characteristic of this kind of bread. Although each layer is partly distended from the adjoining ones, yet the bread as a whole is not light, for the substance of each stratum remains dense and consequently hard of digestion.

Sesquicarbonate of ammonium ($(NH_4)_4H_2(CO_3)_3$) has been used to a considerable extent in confectionaries, and also in making the finer kinds of bread. This salt, on being slightly heated, is split up into carbonic acid, ammonia, and bicarbonate of ammonium, $(NH_4)HCO_3$, all of which are volatile.

In practice the ammonium sesquicarbonate is powdered, and then either mixed with the flour, or dissolved in the water used to make the dough, so that on subsequently kneading the flour with this saline solution, the salt is equally disseminated throughout the mass.

The dough, during the kneading, evolves the characteristic odour of ammonia; the taste is likewise peculiarly saline; but all these peculiarities disappear during the baking, as their source is expelled by the heat. All the ammoniacal salt is not, however, driven off from the loaf, for a careful examination of the crumb will prove the presence of ammonia; but the free alkali is disengaged, and therefore no pungent smell remains.

Carbonate of sodium and hydrochloric acid are used, as already noticed, for raising the dough without destroying any part of the valuable constituents of the flour. The alkaline salt is mixed intimately with the flour, after which the proper quantity of hydrochloric acid necessary to replace the carbonic acid, is mixed with the water, and the dough made. This method was revived in 1848 by Mr. SEWELL, who took out a patent for it. His process was to place the flour in a tub, and to add hydrochloric acid, by means of a series of radial tubes, in the proportion of 45 ozs. of specific gravity 1·14 (containing about 28 per cent. of real acid) to 280 pounds of flour. This flour is made into dough by first adding finely powdered carbonate of sodium in the proportion of 63 grains to the pound, and then the proper quantity of water; the kneading and baking is conducted in the usual way.

Many medical men object to this method of bread-making, as it is calculated to introduce more chloride of sodium into bread than is deemed good for the health of the consumers: moreover, it is almost impossible to obtain commercial hydrochloric acid free from arsenic.

Bicarbonate of sodium and tartaric acid, mixed in equivalent proportions, are likewise substitutes for yeast. The result of their action is the same as the preceding; instead of chloride of sodium, however, tartrate of sodium is formed. A mixture of bicarbonate of sodium and tartaric acid is largely retailed under the name "baking powder."

A patent was many years ago taken out for a mixture of flour with other ingredients, having for its object the rapid making of bread. To each cwt. of flour put 10½ ozs. of finely-powdered tartaric acid of the best quality, and as dry as possible; mix it well with the flour, and pass the whole through a dressing machine, after which allow it to remain untouched for two or three days, that any water present may be absorbed by the flour; afterwards incorporate with the flour 12 ozs. of bicarbonate of sodium, 24 of chloride of sodium, finely powdered and dry, and 8 of ground loaf sugar; mix the whole well, and pass it through a flour dressing machine, when it will be ready for use.

This process is here mentioned, because, though at the time it was unsuccessful commercially, it has of late years been revived, and flour so prepared is somewhat largely advertized.

The bread made from flour mixed with tartaric acid and bicarbonate of sodium has a whiter colour than that made with yeast; it is, however, very plastic,

and wanting in that lightness and spongy texture which characterizes well-made fermented bread.

Dauglish's Process.—As before remarked, the vesicular character of ordinary bread results from the development of carbonic acid gas uniformly throughout a mass of fermenting dough, whereby a loose spongy texture is imparted to what would otherwise be a dense sodden mass of baked flour and water.

In fermented bread the carbonic acid gas generated within the substance of the dough, is a product of the degradation of certain constituents of the flour, namely, the starch and sugar. In DAUGLISH'S process the carbonic acid gas is produced independently, and superadded to the flour, which consequently undergoes no degradation whatever.

Carbonic acid, stored in an ordinary gas holder, is pumped therefrom into a cylindrical vessel of water; the water thus becomes charged with the gas. This carbonic acid water is mixed under a pressure of 100 lbs. on the square inch with the flour. The resulting dough, on the removal of the pressure, immediately becomes vesicular; it is then divided into loaves, and baked in a travelling oven.

The advantages of this process are, according to Dr. ODLING ("Brit. Assoc. Rep." 1859, p. 75)—(1.) Its cleanliness. Instead of the dough being mixed by the naked hands or feet, the bread, from the first wetting of the flour to the completion of the baking, is not even touched by any one. (2.) Its rapidity. An hour and a half serves for the complete conversion of a sack of flour into baked 2 lb. loaves. (3.) Its saving of labour and health. It substitutes machine labour for manual labour of a very exhausting and unhealthful character. (4.) Its economy. Despite the heavy prime cost of the apparatus, yet the use of carbonic acid is found to be cheaper than that of yeast. Moreover, the waste of the saccharine constituents of the flour, necessary in the old process, is avoided in the new one. (5.) Its preventing any deterioration of the flour. In making fermented bread from certain varieties of flour, the prolonged action of warmth and moisture induces a change of the starchy matter of the flour into dextrine, and the bread thus becomes sodden and dark coloured. This change is usually prevented by the addition of alum; but, in operating by the carbonic acid process, there is no time for the change to take place, and consequently no advantage in the use of alum. (6.) The character of the bread. Chemical analysis shows that the flour has undergone less deterioration in bread made by this process than in that made by the ordinary one.

BISCUIT MAKING.—Two classes of biscuits are made—"ships' biscuits" and "fancy biscuits." The former are made of flour and water only. The latter contain, in addition, other ingredients, such as butter, sugar, eggs, spices, &c.

Since 1831 ships' biscuits have been made by machinery, invented by T. T. GRANT of the Royal Clarence Yard. His apparatus consists of a kneading trough, in which a shaft carrying knives works with great rapidity, in order to mix the flour or meal and water into biscuit dough; and two cylinders, of about fifteen hundredweight each, the first of which is called a break-roller, and serves to knead the dough, and the second to spread the paste kneaded by it to the proper thickness of the biscuit before it is cut; these are worked by steam. The break-roller is erected upon a stout table, and can be raised or depressed at pleasure. A heap of the dough from the kneading-trough is placed at one side by two attending workmen, and the roller being temporarily elevated, the dough is pushed under it, when it is brought down and set in motion; by this means the mass is flattened into a sheet and carried to the other side. By reversing the motion of the roller, and lowering it still further, the sheet is rolled back, when the workmen receive it and fold it up in breadths. The dough is made to pass through the rollers three times. As the dough is discharged from the roller the third time, it is about two inches thick, and is then cut into pieces about half a yard square. The operation with the break-roller occupies about five minutes, the dough being kneaded much better than if done by the hand.

The second roller spreads out the squares of dough produced by the first operation to the size of 6 feet by 3, thus bringing the sheet to the proper thickness. The biscuits are then shaped by a cutting press.

The under surface of the cutting press is composed of a series of sharp knives of a hexagonal shape, which cut a piece of dough a yard square into sixty biscuits of a similar form. In some manufactories the stamping or cutting of the biscuit is effected by a roller having circular knives; in this case, however, the sheet of biscuits cannot be immediately introduced into the oven, as there is a space between each circle, and the biscuits have to be picked out separately and laid upon trays. In either case the cut dough is introduced as soon as possible into the ovens, which are very spacious, and heated either by hot air or by a continuous fire, the flues from which pass under and over the baking compartment: in the course of ten to fifteen minutes they are taken out.

The baking ovens are of fire brick and tile. Each one is 13 feet long, 11 feet wide, and 17½ inches in height. They are heated by separate furnaces, so constructed that a blast of hot air and fire sweeps through them, and brings them to the requisite heat in a very short time.

Mode of Working.—The first operation consists in mixing the meal and water; thirteen gallons of water are first introduced into the trough, and then a sack of the meal (which is ground and dressed at the government mills), weighing 280 lbs. When the whole has been poured in by a channel communicating with an upper room a bell rings and the trough is closed. The kneading knives are then set to work. The mixing operation lasts one minute and a half, during which the knives or stirrers make twenty-six revolutions.

The next process is to cast the lumps of dough under the breaking-rollers. The dough is thus formed into large lumps 6 feet long, 3 feet broad, and several inches thick. At this stage the kneading

is still very imperfect, and traces of dry flour may be detected. The masses are now drawn out and cut into a number of smaller ones, about a foot and a half long and a foot wide, and again thrust under the rollers, this drawing out, cutting, and rolling being repeated until the mixture is so complete that no inequality can be detected in any part of the mass.

It should have been stated that two workmen stand, one on each side of the rollers, and as the dough is flattened out, they fold it up, or double one part upon another, so that the roller in its progress squeezes these parts together and forces them to mix. The dough is next cut into small portions, and being placed upon large flat boards, is by machinery conveyed to the extremity of the baking-room. Here it is received by a workman, who places it under the "sheet-roller." The kneading is here completed. The cutting is effected by the cutting-plate, consisting of a network of fifty-two sharp hexagonal frames, each of the size of a biscuit. The cutter is moved slowly up and down by machinery, and the workman, watching his opportunity, slides under it the cake of dough; the cutting-frame in its descent indents the sheet of dough without completely dividing it, leaving sufficient substance to enable the workman at the mouth of the oven to jerk the whole mass of biscuit unbroken into it. The dough is prevented sticking to the cutting-frame by the following device: —Between each of the cutter-frames is a small flat plate (figured with any desired marks), which is free to move up and down, and is loaded with an iron ball weighing several ounces. When the cutter comes down upon the dough, and cuts out fifty-two biscuits, each of these plates yield to the pressure, and is raised up; but as soon as the great frame rises, the weight of the balls acting upon the plates thrusts the perforated sheet off.

One quarter of an hour is sufficient to bake the biscuits, which are afterwards placed for three days in a drying room, heated to from 85° to 90° Fahr.

Fancy biscuits are made and cut into the desired forms by machinery. Captains' biscuits are composed of 10 quarts of water or milk and 15 lbs. of butter to the sack of 280 lbs. of flour; the well known Abernethy biscuits of $8\frac{3}{4}$ quarts milk or water, $17\frac{1}{2}$ lbs. of butter, $17\frac{1}{2}$ lbs. of sugar, $17\frac{1}{2}$ lbs. of carraway seeds, and 280 lbs. of flour.

The butter is mixed with the flour in the dry state, and then the water or milk in which the sugar has already been dissolved, added, and the whole made into dough by a kneading machine.

The temperature of the oven is an important point with the biscuit baker, his object being to bring the materials to a pale brown colour without burning them. Biscuits containing sugar should not be raised to so high a heat as those which are without it. The time usually required for baking is from ten to fifteen minutes.

To give additional lightness, it is the practice of some bakers to add a little sesquicarbonate of ammonium.

Yeast biscuits have, in addition to the other materials, from $4\frac{1}{2}$ to 5 lbs. of yeast to the sack of flour.

ADULTERATION OF BREAD.—Few articles have been subject to such open and flagitious adulterations as bread.

The adulteration of bread now practised, consists either in the mixing of fine flour with that of an inferior quality (the bread made from this compound being sold as of the best description); or of so mixing and otherwise treating the dough as to secure the retention after baking of an abnormal quantity of water.

Mouldy flour, the flour of rye, barley, oats, beans, and rice, and sometimes potatoes in a boiled and crushed state, are frequently used for these purposes.

A very frequently adopted method for securing the retention of a large quantity of water by the bread is "slack-baking," or under-baking. This is usually effected by introducing the dough into an over-heated oven; the outside of the loaf is rapidly browned, whilst the interior remains uncooked. According to URE, a baker by this means sometimes obtains as many as 106 4-lb. loaves from a sack of flour, and by the addition of boiled rice to the dough as many as 116 quarter loaves from 280 lbs. of flour.

The quantity of water in bread is determined by heating a known quantity for some time at about 212° Fahr. Good new bread should contain at most 45 per cent. of water.

The most frequent adulterant of bread is alum. It enables the baker to use damp flour, which has already undergone to an exaggerated degree the change which always takes place to a slight extent in the process of bread-making, and which consists in the conversion of the starch into sugar and dextrin. Alum stops this change, and for this reason some chemists justify its moderate use by bakers.

Dr. ODLING says:—"One very important use of alum is to prevent any undue deterioration of the starch during the process of raising or baking. If we mix a solution of starch with infusion of malt, in the course of a few minutes only the starch can be no longer detected, being completely converted into dextrin and sugar; but the addition of a very small quantity of alum either prevents entirely, or greatly retards, the transformation. The action of diastase on starch is very gradual, but here also the interference of the alum is easily recognizable. Bread made with infusion of bran or infusion of malt is very sweet, sodden, brown coloured, and so sticky, as almost to bind the jaws together during its mastication. But the addition of alum to the dough causes the loaves to be white, dry, elastic, crumbly, and unobjectionable, both as to taste and appearance.

"The worse the character of the bread which the flour alone would yield, the more striking is the effect of the alum. That alum does oppose the transformation of starch into sugar during the process of bread-making is indisputable; and this action is quite sufficient to account for the whiteness, the dryness, and the non-adhesiveness which result from its employment."

LIEBIG's explanation of the effect of alum in purification corresponds with this view. He says that in damp flour there is produced, by a reaction

of the gluten and starch, acetic and lactic acids, which render the gluten soluble in water, and that alum and other mineral salts renders this gluten again insoluble.

PAYEN entertained the same idea as LIEBIG. He says "that when wheat has been badly kept, or when moist flour has become altered during its warehousing or transport, from three to six thousandths of alum are occasionally added, so as, in some degree, to restore to the gluten the consistency that it has lost."

Lime water has been recommended by LIEBIG to effect the same result as that now accomplished by means of alum, and has been used to a considerable extent by the Glasgow bakers. Dr. ODLING has found by experiment that lime water acts quite as efficaciously as alum in preventing the action of diastase, and the consequent transformation of starch into sugar. It seems to have scarcely any action upon the fermentation induced by yeast, or at any rate a much less action than alum, which undoubtedly retards the process somewhat. It yields a very white agreeable bread, having a rather more porous texture than ordinary bakers' loaves, and being quite free from any sourness of taste or smell.

The following are the modes adopted for the detection of alum in bread:—

KUHLMANN's process was formerly much in vogue until its fallacious character was exposed by Dr. ODLING. It is as follows:—Incinerate about half a pound (3500 grains) of bread in a crucible, and after having pulverized the ash treat it with nitric acid. Evaporate the mixture nearly to dryness, dilute with half an ounce of distilled water, and add to the whole an excess of caustic potash solution; boil and filter; neutralize the filtered liquid with hydrochloric acid, and add a slight excess of ammonia. Collect the alumina thus precipitated in a filter, wash, dry, ignite, and weigh it. Every 100 grains of alumina correspond to about 467 grains of alum. Dr. ODLING examined the ashes of forty-six samples of wheat and other grains, with the result that in twenty-one instances he obtained the white precipitate said to be indicative of alumina and alum. He says KUHLMANN's process is possessed of rare merits. It will never fail in detecting alumina when present, and will often succeed in detecting it when absent also.

Dr. NORMANDY took 1500 grains of bread from the middle of the loaf, cut or crumbled the bread, and placing it on a platinum tray, exposed it to a cherry red heat until completely charred. The charcoal thus obtained he ground in a mortar into very fine powder, and then returned to the platinum tray and exposed again to a cherry red heat until reduced to a gray ash. This ash was then moistened with ammonium nitrate, and heated to redness to burn off the last remaining portions of charcoal. He then poured on the ashes a few drops of hydrochloric acid, and in the course of a minute or so washed the whole in a porcelain capsule, and evaporated to absolute dryness, in order to render the silica perfectly insoluble. The perfectly dry residue was then drenched with hydrochloric acid, boiled with water, and filtered. The acid filtrate was then nearly neutralized with potash, and the whole thrown on a filter, and after slightly supersaturating the strong alkaline filtrate with hydrochloric acid, carbonate of ammonium was added in excess, and if a white floculent precipitate made its appearance it was further examined by collecting a portion on a platinum hook and heating it. On moistening the mass with cobalt nitrate and again heating, if without fusing it assumes a beautiful blue colour, the presence of alumina is presumed. The filtrate should be examined for sulphuric acid; if alum had been present it should yield an abundant precipitate with chloride of barium.

W. CROOKES varies this process thus: he found the great difficulty was to devise a method of analysis which should not confound other things with alumina. It was easy to frame various modes of operating by which a minute trace of alumina could be detected; but these reactions were equally sensitive whether alumina was present or not. For the process which he has at last adopted he claims that, though tedious in its manipulation, it has at least the merit of not showing the presence of alumina when that body is absent. He proceeds thus:—

The bread, of which at least 500 grains should be taken, is first to be incinerated in a platinum or porcelain dish, until all volatile organic matter has been expelled and a black carbonaceous mass remains. The temperature must not be raised much beyond the point necessary to effect this. Powder the coal thus obtained, and add about 30 drops of strong sulphuric acid, and heat until vapours begin to rise; when sufficiently cool, add water and boil for ten minutes. Filter, and evaporate the filtrate until the fumes of sulphuric acid begin to be evolved, when 10 grains of metallic tin and an excess of nitric acid must be added, together with water, drop by drop, until action between the acid and metal commences. When all the tin is oxidized, add water and filter. Evaporate the filtrate until fumes of sulphuric acid are again visible, when more water must be added, and the liquid again filtered if necessary. To the clear solution now add tartaric acid, then ammonia in excess, and sulphide of ammonium. Evaporate the liquid containing the precipitate suspended in it in a dish, until all the smell of sulphide of ammonium has disappeared. Filter, evaporate to dryness, and ignite to get rid of the organic matter. Powder the black ash, boil it in moderately strong hydrochloric acid, filter, add a crystal of chlorate of potash, and boil for a minute. Now add chloride of ammonium and ammonia, and boil for five minutes. If at the end of that time any precipitate is observed, it will be alumina. From the filtered solution, if oxalate of ammonia be added, the lime will be precipitated; and if to the filtrate from this, ammonia and phosphate of sodium be added, the magnesia will come down.

Dr. C. MEYMOTT TIDY says, to detect alumina thoroughly, char (not incinerate) 1000 grains of the

crumb of bread in a covered platinum crucible. Powder the charred mass in a clean iron mortar, and put the powder into a glass flask with a narrow neck; add 2 drams of hydrochloric acid, half a dram of nitric acid, and 2 drams of water. Gently heat to dryness on a sand bath, when dry boil for a few minutes with half an ounce of water, containing an excess of pure caustic soda made by the direct oxidation of the metal; about 10 grains will be sufficient. Filter, and again boil the charred mass with 2 drams of water; filter through the same filter paper, and add the filtrate to the former one. This should be allowed to stand all night, so that the liquid may filter through completely. Carefully neutralize the filtrate with hydrochloric acid; add now 5 grains of phosphate of sodium, and then ammonia in slight excess, the precipitate is weighed as phosphate of aluminium, 100 parts of which represent 384 parts of crystallized alum. The main points to be attended to in this process are:—1st. Only to char the bread; to incinerate it is fatal, the alumina becoming changed to an insoluble form, and some of it dissipated as chloride. 2nd. To keep the solution in as small a bulk as possible. 3rd. To see that the precipitate is entirely phosphate. (NORMANDY'S "Chem. Analysis," ed. Dr. NOAD; 1875, p. 90.)

Some bakers buy rock alum in powder, and mix it up in certain proportions with salt; the majority, however, make use of an article known in the trade as *hards* and *stuff*. This consists of a mixture of alum and salt. It is kept in bags holding from a quarter to 1 cwt., and is sold by druggists, who supply either the baker or the corn chandler. It is not easy to ascertain the proportion of alum and stuff used in the preparation of bread; it may, however, be stated as a general rule, that the worse the flour, the greater is the proportion of these ingredients used.

Sulphate of copper, blue vitriol, was at one time a favourite adulterant with many bakers, particularly in Belgium and the north of France. The advantages which the bakers derive from it are numerous. They find it easy to use with it flours of a medium quality and mixed. The panification is more rapid, the soft part of the bread and crust have a finer appearance, and lastly, they are enabled to add a greater quantity of water.

Sulphate of copper exercises an extremely energetic action on the fermentation and raising of bread, even when the copper salt is used in the proportion of 1 grain of sulphate to 7½ lbs. of bread. The proportion which produces the greatest enlargement, or raising, is from one-thirty-thousandth to one-fifteenth-thousandth part.

The largest quantity of sulphate that can be employed, without detracting from the beauty of the bread, is one-four-thousandth part; in a greater proportion the bread is very watery, and presents large openings; with one-eighteen-hundredth of the salt the dough can by no means be "raised," all fermentation is arrested, and the bread acquires a greenish colour.

The effects produced by sulphate of copper in the fabrication of bread are nearly the same as those obtained with alum, but the latter must be used in much more considerable quantities.

To determine satisfactorily these very minute quantities of the copper salt which might be contained in the bread, M. KUHLMANN had recourse to the following method, which he put to the test by introducing with his own hand into bread mere traces of sulphate of copper; one part in seventy thousand, for example, which represents one part of metallic copper to about three hundred thousand parts of bread.

In a platinum capsule 200 grammes of bread are completely incinerated. The produce of the incineration, after being thoroughly reduced to a very fine powder, is mixed in a porcelain capsule with 8 or 10 grains of nitric acid. This mixture is submitted to the action of heat till nearly the whole of the free acid is evaporated, and only a pitchy paste remains, which is mixed with about 20 grammes of distilled water, assisting its solution by heat. It is then filtered so as to separate the parts not attacked by the acid, and into the filtrate a small excess of liquid ammonia is poured, with some drops of solution of subcarbonate of ammonia. After cooling, the white precipitate formed in abundance is separated by percolation, and the alkaline liquor is submitted for some moments to ebullition, to dissipate the excess of ammonia, and reduce it to about a fourth of its volume. This liquor being rendered slightly acid by a drop of nitric acid, it is divided into two parts: the one part is submitted to the action of ferrocyanide of potassium, the other to sulphide of hydrogen, or sulphide of ammonium.

If the bread should contain only *a seventy-thousandth part of sulphate of copper*, its presence will be rendered apparent by the immediate pink or rose coloration of the liquid, on addition of ferrocyanide of potassium, and the formation, after resting some hours, of a light crimson precipitate; or by the appearance of a slight fawn colour, with the subsequent formation of a brown precipitate, on addition of sulphide of hydrogen or ammonium.

Sesquicarbonate of ammonium is used to raise and whiten bread. As before stated, the whole of the ammonia is not expelled by the heat of the oven. The best way to proceed for its detection is to mash half a pound of the bread in cold distilled water, and after half an hour strain off the liquid, add a few drops of hydrochloric acid, and evaporate to dryness in a water bath; the dry residue is next treated with a little strong caustic potassa, when ammonia will be disengaged if present.

BROMINE.—*Brome*, *Bromure*, French; *Brom*, German; *Brominium*, Latin. Symbol, Br. Atomic weight, 80.—This element was discovered by BALARD in 1826 in the mother liquor from salt works at Montpellier. In its nature bromine closely resembles chlorine and iodine, with one or other of which it is always found associated. The relations of these three bodies have been made the subject of some beautiful speculations by DUMAS. "Regarding chlorine, bromine, and iodine as a triad, between

the first and last there is recognizable a well-marked progression of qualities. Thus, chlorine is a gas under ordinary temperatures and pressures, bromine a fluid, iodine a solid; in this manner displaying a progression in the difference of cohesive force. Again, chlorine is yellow, bromine red, iodine black, or in vapour a reddish violet. Here we have a chromatic progression; and strange to say, if we refer to the atomic or equivalent weights of the three, a numeral progression will be observable. Thus, the weight of chlorine is 35, of bromine 80, and of iodine, 125; and now, if the atomic weights of chlorine and iodine be added together and divided by two, the result will be the atomic number for bromine. Hence it follows, if we could cause the union of half an atom of chlorine with half an atom of iodine, we might hope to get, to form, to create an atom of bromine!"

At ordinary temperatures bromine is a liquid body, which when in quantity appears of a blackish-red colour, but when examined in thin layers hyacinth red. It is very volatile, giving off, when exposed to the air, reddish vapours. At —8° Fahr. (—22°·2 C.) it congeals to a yellowish-brown, brittle, lamellar, crystalline mass, which remains solid when the temperature is raised to 10° Fahr. (—12°·2 C.). Bromine boils at 137° Fahr. (58°·3 C.)—Andrews—giving off vapour of the density, according to Mitscherlich, of 5·54, 100 cubic inches of which at 60° Fahr. (15°·5 C.) weigh 167·25 grains.

Like the other elementary bodies, it is not altered by heat and light, and is a non-conductor of electricity. It is soluble in water, alcohol, and ether; it is a powerful bleaching element, destroying, like chlorine, the blue of indigo.

Organic matters are acted upon by it, and it is very destructive to animal life. It stains the skin yellow, but less intensely than iodine, and the colour soon disappears.

Bromine is very volatile; a drop put into a flask soon fills it with vapour, resembling that of fuming nitric acid, and a taper plunged into it burns for some moments, with a flame green at the base and red at the top, as with chlorine, and is then extinguished.

No anhydrous oxide of bromine is known, and of its oxygen acids, the existence of only one, bromic acid ($HBrO_3$), has been thoroughly established.

Tin, arsenic, antimony, and potassium produce vivid combustion when thrown into liquid bromine, and become bromides. Iron, copper, bismuth, and mercury, combine quietly with the vapour of bromine at ordinary temperatures, but if heat is applied, with incandescence.

Bromine dissolves sparingly in water and alcohol, but with great facility in ether.

Bromine replaces part of the hydrogen in many organic compounds. In this way bromacetic acid is formed. Steam and vapour of bromine passed through a red hot tube yield hydrobromic acid (HBr) and oxygen.

Bromine is found in all sea waters, and in the water of salt springs. It also occurs, together with iodine, in the ash of sea-weed. Bromide of silver is found native in Mexico and Chili. Some fresh water plants have been found to contain it in very minute quantity.

The source from which bromine is principally manufactured is bittern—the mother liquor of sea-water or saline springs, from which the chloride of sodium has been separated by crystallization. Its extraction from this liquid, though not a very complicated process, requires delicate attention. Its separation from the metals with which it may be in combination—sodium or magnesium—is dependent upon the greater affinity which chlorine has for these; and hence, when a current of this gas is transmitted through the solution, the bromine is liberated and a chloride of the metal is formed. That the bromine is disengaged is known by the orange-yellow tint it communicates. Care must be taken that an excess of the chlorine is not used in liberating it, lest a portion might be expelled. If the liquor be now boiled in a close vessel, red vapours of bromine are evolved, which are condensed into the liquid state in a receiver surrounded with ice. The bromine is afterwards purified by solution in ether. This process is not commercially available.

The method now most commonly employed is as follows:—

Having deprived the mother liquor of sea water or brine of as much of its salt as possible, by evaporation and crystallization, chlorine is developed in the liquor, which now contains the bromine principally as magnesium bromide, by acting upon peroxide of manganese (MnO_2) with hydrochloric acid, or if sufficient salt still remains in the mother lie, sulphuric acid may be substituted.

Kreuznach uses 1 ounce of the binoxide and 5 or 6 of commercial hydrochloric acid to about 4 quarts of the mother liquor, and distils the whole slowly by the heat of a sand-bath as long as vapours of bromine are evolved. To avoid loss by the formation of hydrobromic acid through decomposition of the magnesium bromide by water during concentration, Desfosses recommends previous saturation of the mother liquor with chalk.

Bromine is also extracted from the mother liquor from the ashes of seaweeds (*varec*). After the separation of the alkaline chlorides and sulphate, the liquid contains iodine and bromine in the proportion of about 8 of the former to 1 of the latter. The iodine is precipitated by passing a current of chlorine until no precipitate is given on testing a sample of the liquor (after filtration) with a solution of chlorine or iodide of potassium. Sometimes the iodine is precipitated (as cuprous iodide and free iodine) by a mixture of sulphuric acid and sulphate of copper. The reaction is:—

$$\underset{\text{Sulphate of Copper.}}{Cu_2SO_4} + \underset{\text{Sodium Iodide.}}{2NaI} = \underset{\text{Sodium Sulphate.}}{Na_2SO_4} + \underset{\text{Cuprous Iodide.}}{Cu_2I} + \underset{\text{Iodine.}}{I.}$$

The filtered liquor contains the bromine, and is submitted to distillation with a mixture of sulphuric or hydrochloric acid and binoxide of manganese, in the manner previously described.

The crude bromine obtained from any of the above sources is distilled over chloride of calcium,

and the aqueous distillate well shaken with ether: to the ethereal solution caustic potash is added till all colour disappears (bromate and bromide of potassium are formed), and is then evaporated to dryness and ignited in a crucible, when the whole of the bromate is converted into bromide of potassium. From bromide of potassium, free bromine is obtained by distillation with suitable quantities of sulphuric acid and manganese binoxide.

Or the mother liquor of the varec, free from iodine, may be neutralized with baryta, evaporated to dryness, and the residue calcined; it then contains a mixture of chloride and bromide of barium, from which the latter may be separated by solution in concentrated alcohol (in which bromium chloride is insoluble). The barium bromide is then treated with sulphuric acid and manganese binoxide as in the other cases.

LEISLER separates bromine from mother liquors containing it, by adding bichromate of potassium and an acid, and heating the mixture. The bromine is volatilized and is collected in a condenser filled with scrap iron. The bromide of iron formed is dissolved by the condensed steam, and runs off from the receiver; from it free bromine, or any desired bromine compound, can be procured by the usual processes.

Bromine is used for photographic purposes; in medicine; and as bromides of ethyl, methyl, and amyl, for making HOFMANN'S blues, and for the manufacture of alizarine from anthracene, &c. For further details of the mode of preparation see IODINE.

CADMIUM.—See PAINTS AND PIGMENTS.

CALICO-PRINTING.—See DYEING.

CANDLE.—*Chandelle*, *Bougie*, French; *Licht*, *Talglicht*, tallow candle, *Kerze*, wax candle, German.—The principal materials used for making candles are tallow (*i.e.*, clarified animal fats), palm oil, paraffin, and wax.

The researches of CHEVREUL and BRACONNOT have made it clear that fats, as they occur in nature, are a mixture of the simple fluid and solid fats, olein, stearin, and margarin, in variable proportions, the fusibility of the compound fat varying as the solid or liquid constituents preponderate. Fats are divided into three classes—1, unsaponifiable fats; 2, saponifiable fats; 3. fatty acids, or soap acids.

Unsaponifiable fats (such as paraffin) remain unchanged after boiling with aqueous potash.

Saponifiable fats (glycerides) when boiled, or left long in contact with alkaline solutions, are resolved gradually into—1, fatty acids, which unite with the alkali and form a soap salt; and 2, glycerin.

The fatty acids combine with most bases to form salts, and can be displaced by stronger acids; they therefore are classed as organic acids. They are divided by their respective boiling points into volatile fatty acids and fixed fatty acids.

These results of CHEVREUL have been confirmed and extended by BERTHELOT and HEINTZ.

BERTHELOT has succeeded in reproducing fats by the direct union of the fatty acid and glycerin, water being thrown out of combination. HEINTZ has corroborated most of CHEVREUL'S work, and has shown that the fats in tallow and palm oil consist essentially of stearic, palmitic, and oleic acids, in combination with glycerin—stearin, palmitin, and olein are therefore glycerides; but differs from him by regarding the margaric acid, obtained by the saponification of natural fats, as a compound of palmitic and stearic acids.

Stearin yields 95·7 per cent. of stearic acid ($C_{18}H_{36}O_2$), melting at 156°·5 Fahr. (69°·2 C). Palmitin yields 94·8 per cent. of palmitic acid ($C_{16}H_{32}O_2$), melting at 143°·6 Fahr. (62°·0 C). Olein yields 90·3 per cent. of oleic acid ($C_{18}H_{34}O_2$), which is fluid at ordinary temperatures.

TALLOW.—Beef and mutton tallow are the animal fats most used for candle-making. They consist chiefly of stearin, palmitin, and olein, the stearin having the predominance, but varying in quantity with the species of the animal (beef contains less than mutton tallow), its age, and kind of food.

Beef fat or tallow has a yellowish colour and a peculiar odour; it is hard and brittle, dissolves in about 40 parts of alcohol, and melts at 100° Fahr. (37°·7 C.).

Mutton suet or sheep fat, when fresh, has very little odour, though it acquires in a short time a rancid smell, probably from decomposition of traces of albuminous matter, and also of the olein; this smell is stronger if the suet be exposed to the air. It fuses between 100° and 106° Fahr. (37°·7 to 41°·1 C.); it is white, hard, and brittle; quite insoluble in water, and only partially so in alcohol, 100 parts of which, at a density of 0·820, and boiling temperature, take up only about 2·3 of the fat. Mutton suet solidifies at 100° Fahr. (37°·7 C.); but in so doing its temperature rises to 111° Fahr. (43°·8 C.).

Lard or hogs' fat has of late years been much employed in the United States for the manufacture of candles, the olein being removed. The quality of the lard varies with the nature of the animals' food; for instance, the fat of hogs fed upon potatoes or grain is hard, and possesses great body. When the animals are fed upon malt, their lard is next in quality to the preceding; but the fat of such as consume distillers' wash contains very little body; and is besides soft, oleaginous, and of a yellowish colour. It fuses at 81° Fahr. (27°·2 C.).

All of these fats are separated from the cellular tissue and other matters by heat; the lower the effective temperature used the better will be the tallow. The operation is technically termed "rendering;" the department where the work is conducted was formerly called a "foundry."

The best time to render animal fat is while it is fresh; for when allowed to remain for a time before being worked, more especially if undried, it undergoes partial decomposition, which renders its after working into fine tallow very difficult.

The requisites for a foundry for purifying tallow and other fats are, a drying-house, steam-jackets or boilers, tubs, and presses. The fresh fat is strung up in the drying-house to harden it and to drive off the moisture. In a well-aired chamber long horizon-

tal rafters are supported either by cords or upright pillars, and upon these the rough tallow is strung till it becomes dry. The tallow is then minced by appropriate machinery. In large foundries this is done by steam machinery; but in small melting works the tallow is chopped by a lever knife fixed upon a table.

The minced tallow is collected in a basket, and taken to the melting vat or boiler for the purpose of melting it.

In small factories the boiler is a copper vessel, so set that the flame from the furnace comes in contact with its bottom only; this is to prevent possible carbonization. To keep the "unrendered" fat from contact with the heated metal, a certain quantity of melted tallow, or a layer of water, is always retained in the bottom of the boiler.

The lower part of the boiler is generally the shape of an inverted cone, but the sides slope inwards towards its mouth, to prevent inconvenience from the spirting of the melted suet. The chopped tallow is thrown into the boiler, and the fire so fed as to communicate a moderate heat. As soon as the bath of rendered tallow on the bottom of the copper becomes melted, the entire contents are kept regularly stirred, till the fat is completely separated from the membranes which constitute the cells and adipose tissue. These contract after having burst and emptied themselves, and rise to the surface. They are technically termed "cracklings." When the melting is complete the rough tallow is ladled out into a large tub, whence it is afterwards removed to small ones, arranged on the floor of the foundry at equal distances from the boiler. A simple filter, consisting of a wicker or wire basket thickly woven, or a brass wire-gauze sieve, is placed on the tub to prevent the cracklings from passing through. Some melters press a filter sieve of coarse wire into the melting vat, and ladle out the liquid which rises through its meshes, passing it afterwards through a finer sieve placed upon the tub. Before distributing the melted fat into the smaller tubs, the contents of the larger one are allowed to deposit any impurities that may have passed through the sieve, but the tallow must not be allowed to solidify.

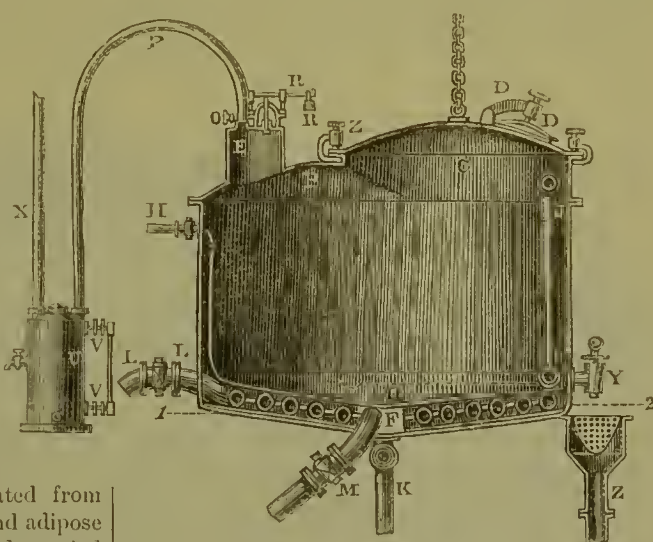
After all the liquid fat is removed the "cracklings," which still retain some fat, are thrown into boiling water; this melts the fat, which floats to the surface, when it is ladled out and boiled, to remove water from the suet; the cracklings remaining on the sieves and deposited in the tub are treated in a similar manner. The whole of the water cannot be thus separated, and therefore recourse is had to heat and pressure. Hydraulic presses, heated by steam pipes, are commonly used.

The cracklings are introduced while warm, and the power of the press exerted as long as any fat exudes. The residuary cake, which is known as "greaves," is sold as food for dogs and swine.

An ingenious mode of tallow melting has been devised by D'ARCET; it has, however, the somewhat serious drawback that the residues are useless as food for animals.

A jacketed copper pan, closed in at the top and of sufficient strength to resist 50 lbs. internal pressure on the square inch, is used as melting vat. The chopped suet is introduced through a man-hole in the lid, and steam passed into the jacket. Sulphuric acid, diluted with from 20 to 50 parts of water

Fig. 1



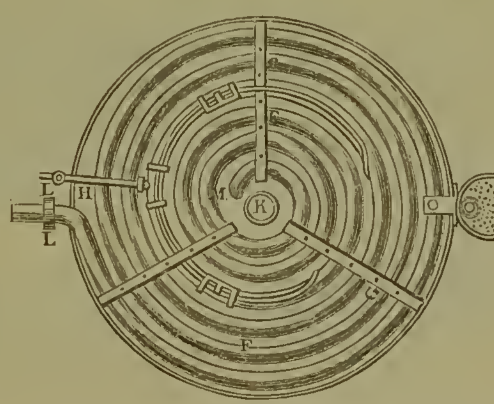


Fig. 2.

(according to the quality of the rough fat), is then added in the proportion of 1 part dilute acid to 100 parts of fat, and the lid of the pan firmly secured. The mixture is allowed to boil for several hours, the temperature being kept at from 220° to 230° Fahr. (105° to 110° C.). The animal membranes dissolve in the sulphuric acid, whilst the purified fat separates and floats on the top of the acidulated water. The tallow is drawn off by a tap at a suitable height, the tube of which pierces through the jacket to the interior of the pan, where it is continued by a flexible tube attached to a float, so balanced as always to be kept at the boundary of the two liquids.

By this process 85 per cent. of pure white tallow can be extracted from ordinary rough fat.

Melting by fire yields only 80 per cent. of tallow, which is, moreover, apt to be discoloured by charring.

FOUCHÉ's process is an adaptation of D'ARCET's. Fig. 1 shows a vertical section of the melting pan, and Fig. 2 is a horizontal section (across the line, 1—2, Fig. 1).

The pan is furnished with a rivetted copper dome, B, which is provided with a manhole, C, through which the fat is introduced. The lid of the manhole is lifted by a chain passing over a pulley; to the other end of the chain a balancing weight is attached. D D shows an opening through which the progress of the operation can be observed. The lid is secured by a screw passing through the arm, D. The vapours are conducted away by the pipe, P, access to which is gained by opening the tap, O. On the cap, E, is a safety-valve, R R, with weight attached. The condenser, U, stops the greater part of the vapours given off; the remainder pass by X into the chimney shaft. V V is a gauge showing the contents of U. The boiler is heated by the steam worm, F, supported just above the bottom of the pan by the stays, G (Fig. 2). The steam passes in at L, and the condensed water returns through M to the boiler. The fat is kept in motion by a steam jet issuing from the small pipe, H H. The vessel is emptied by lowering the tube, J (which has a sieve at its upper

Fig. 3.

end) until it falls into the position shown by the dotted line. The drawing-off tap is shown at Y. The pan is emptied of the acidulated water by the pipe, K.

1000 lbs. of rough fat and 80 lbs. of water are first introduced, and then $2\frac{4}{10}$ lbs. of sulphuric acid of 66° Fahr., diluted with 16 lbs. of water. The steam must have the temperature of 255° Fahr. (about 45 lbs. pressure per square inch). In the vessel itself half this pressure is sufficient, and the safety-valve on E is allowed to blow off when this is reached. The rendered tallow is run off by the pipe, Z, which has a sieve at the top to keep off coarse impurities.

EVRARD of Douai uses a weak solution of caustic soda in place of sulphuric acid, to break up the fat cells.

The rough fat is placed in an ordinary cylindrical melting copper, heated by a furnace, or by steam, with 1 to 1·5 per cent. of soda dissolved in much water. The boiling alkaline liquor penetrates the membranes and breaks them up, so that the melting fat readily escapes from its enveloping tissue. The temperature is never allowed to exceed 212° Fahr. (100° C.).

Fig. 3 represents six vats for tallow melting by steam, seconded by the use of alkaline liquor. The steam pipe, by which the ebullition is effected, is visible at the bottom of the three upper vessels.

The heating is effected by simply passing high-pressure steam through the bottom of the vessels into the centre of the mass of fat.

Tallow as it comes from the melters is generally

of a bad colour, besides being more or less rancid; it has therefore to be purified before manufacturing it into candles. Various processes have been tried at different periods for this purpose. By WATT'S process the tallow is bleached by mixing with it sulphuric and nitric acids, together with bichromate of potassium and oxalic acid. When the fat is nearly melted in the steaming tub the nitric acid is added in the ratio of 1 lb. to a ton of tallow; but before introducing it, it is diluted with 1 quart of water and 2 ounces of alcohol, naphtha, ether, or spirit of turpentine, the whole being then boiled for half an hour; after which the fat is washed to free it from any particles of the materials employed in the purification. In this process the materials taken seem to neutralize the effect of each other, for, whilst the bichromate of potassium and nitric acid supply oxygen for bleaching the fat, the oxalic acid and alcohol, or other liquor, divest these compounds, or the fat, of oxygen; however, the patentee alleges that the intended effects are produced to satisfaction.

A very effective process, which the editor had the opportunity of watching for some years, is to melt the tallow in any convenient vessel, over which a hood connected with the chimney shaft is fixed to carry off the disagreeable smell, and heating it by steam of greater or less pressure, from 170° to 230° Fahr. Streams of air are then forced through the molten tallow by means of perforated pipes placed at the bottom of the vessel, and a blowing apparatus to which they are connected. Unless the colour of the tallow is very bad, its bleaching will be effected in ten to fifteen hours. Even palm oil subjected to this treatment is brought to a cream colour in about twenty-four hours.

Some candlemakers improve upon this method by adding carbonate of potassium to the melted fat, agitating it, allowing it to repose, and when the whole of the sedimentary matter has settled down, then blowing the air through it as above.

By WATSON'S process the purification is effected by permanganate of potassium ($K_2Mn_2O_8$), "chameleon mineral." The purifying element in this case, as in those processes already described, is oxygen. In the present case this is derived from the reduction of the permanganic acid to sesquioxide of manganese, *i.e.*, manganic oxide (Mn_2O_3). The bleaching is executed by melting the fat in a leaden or wooden tank by means of steam, and gradually mixing it with a solution, in which the permanganate is dissolved to the amount of about 1-20th of the weight of the fat taken. When both are intimately mixed by brisk agitation, a sufficient quantity of dilute sulphuric acid to communicate a slightly acid reaction is added, in order to set free the permanganic acid of the chameleon mineral; the whole is then briskly stirred for about an hour, during which time the temperature of the mixture should be maintained at between 150° and 212° Fahr. (65°·5 to 100° C.), as may seem desirable. The contents of the tank are then allowed to rest, that the oily matters and the acid solution may separate, the former rising to the surface, from which it is drawn off into another vessel, and remelted in a fresh quantity of hot water and cooled, for the purpose of washing it. From time to time samples must be taken from the bath of melted fat, and cooled, to observe if the proper degree of whiteness is attained; and if extra purified tallow is to be produced, a fresh quantity of the chameleon mineral dissolved in water may be added.

STEARIN AND STEARIC ACID.—In preparing stearin and stearic acid for candles, the object is not to obtain these bodies in a state of absolute purity, but to have them as free as possible from the oleic acid, glycerin, and fatty acids of low melting points, to which they are united in the natural fats.

Stearin, Tristearin, Stearate of Glyceryl $(C_{57}H_{110}O_6) = \left.\begin{matrix}(C_3H_5)\\(C_{18}H_{35}O)_3\end{matrix}\right\}O_3$.—CHEVREUL'S stearin is obtained from mutton suet or tallow by dissolving it in boiling alcohol, and recrystallizing the fat which separates out, till the boiling point becomes constant. LECANU melts mutton fat in the water bath with its own weight of ether, stirring all the time, and subjects the mass when cold to strong pressure, to remove the fluid constituents of the fat, and recrystallizes till the melting point rises to 62° C. After thirty-two crystallizations, however, the fat thus treated is still a mixture of tristearin and tripalmitin. According to BONIS and PIMENTAL pure tristearin may be separated from Bridonia tallow by recrystallization, and yields by saponification an acid having the melting point of stearic acid. It is a white substance, and as it deposits from alcohol it forms snow-white, glistening scales; it is not greasy to the touch, is easily powdered, and melts at 125° Fahr. (51°·6 C.). It readily dissolves in hot alcohol and ether, but is almost insoluble in water and ether in the cold.

Stearic Acid, $C_{18}H_{36}O_2 = \left.\begin{matrix}C_{18}H_{35}O\\H\end{matrix}\right\}O$.—This acid is readily obtained by saponifying stearin with potassium hydrate, decomposing the soap formed with hot hydrochloric acid, collecting the flocculent stearic acid upon a filter, washing it with cold alcohol, and dissolving in boiling alcohol. The solution thus obtained is set aside to cool, when the stearic acid crystallizes out in white glistening needles or leaflets, which appear under the microscope as elongated lozenge-shaped plates. It is inodorous and tasteless, does not feel greasy to the touch, and dissolves in all proportions in boiling alcohol and ether, from which it separates on cooling. It melts at about 157° Fahr. (69°·4 C.) to a colourless oil, which on cooling solidifies to a white, scaly, crystalline mass. Impure stearic acid crystallizes in needles. The alcoholic solution of stearic acid gives a slightly acid reaction with blue litmus paper; it decomposes alkaline carbonates to the amount of one-half in the cold, and completely at the boiling point. It burns like wax, and forms the chief ingredient of stearin candles, to which reference will be hereafter made.

The most convenient way of preparing stearic acid is the following:—Beef or mutton tallow is saponified with soda liquor, the soap decomposed by heat-

ing with water and dilute sulphuric acid, and when cold the fatty acids removed and washed with water. They are then dissolved in as small a quantity of hot alcohol as possible. On cooling the stearic acid separates, the oleic acid remaining in solution. After draining the precipitated stearic acid, it is subjected to strong pressure, redissolved in alcohol, and, after cooling, pressed as before. Pure stearic acid is obtained by fractional precipitation with acetate of lead, barium, or magnesium, when the stearate separates before the salt of palmitic acid.

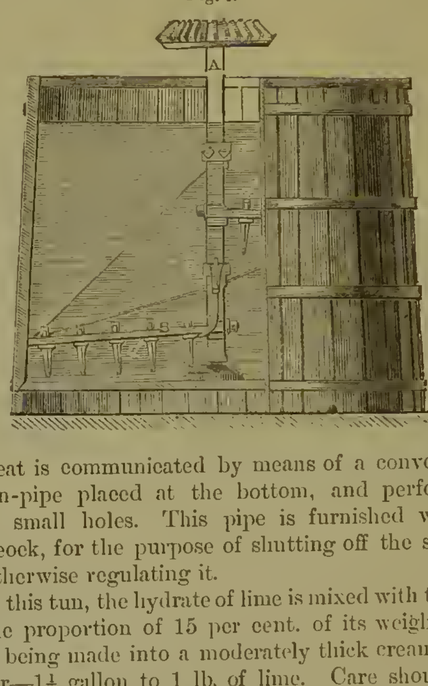
Chevreul's investigation on the fats was the first step towards the employment of stearic acid and stearin in the preparation of candles; additional information was added to that derived from the researches of this chemist by the labours of Braconnot and others; and ultimately the tallow treated according to the processes pointed out by them, and divested of its olein and glycerin, was used for the making of candles by Cambaceres. The manufacture, however, did not succeed on account of the imperfections of the methods adopted, which were such that better illuminating materials could be procured at a less cost than the new patent candles. On the Société d'Encouragement offering a premium of 4000 francs to the person who would discover a means of manufacturing a cheap, and at the same time good candle, the spirit of inquiry was excited by the munificent reward, and as the result a great improvement took place, which much lowered the cost of candles, while in point of quality they were considerably improved, instead of being deteriorated. From time to time various alterations have since been introduced in the method of working.

Gay-Lussac's patent, in 1825, specified that the fat, after being rendered, should be boiled with solutions of either potash or soda, in order to form a soap, and to remove the glycerin with which the fatty acids are united. The soap thus produced was next to be decomposed by an acid, in a capacious vessel, and in the presence of much water, the whole being heated by steam injected in any convenient way, and kept well agitated during the operation. After the decomposition was completed, the contents of the vessel were allowed to remain at rest for some time, till the fatty acids collected upon the surface of the water, which could be drawn off by a discharge-cock at the bottom of the tub, carrying with it the alkaline salts resulting from the decomposition of the soap. To free the fatty acids completely from any traces of the alkali or saline substances, a quantity of fresh water was thrown in upon the fat, the steam again allowed to enter, and the contents of the tub agitated as before; and after a short time the whole was left to cool, and finally the water drawn off from the solid layer of fatty bodies. The mass was then submitted to considerable pressure, in an apparatus similar to that used in extracting oil from seeds, by which means the liquid oleic acid was discharged, leaving crude stearic acid mixed with other fatty acids. Margaric acid was formerly supposed to be among those, but this was shown by Heintz to be only a mixture of palmitic and similar fatty acids of lower melting points. Lime is now employed instead of potash and soda, to set free the glycerin, and form lime salts with the several fatty acids. This greatly lessens the price of stearin candles.

The vessels employed in conducting these operations in most factories, are large wooden tuns closely covered, and into which a steam-pipe enters from an adjacent boiler. The suet or rendered tallow is introduced into these tuns and melted; then pumped out into a second tun of a similar construction, but supplied with machinery for agitating the contents.

The decomposing or saponifying tun is represented in the annexed woodcut—Fig. 4. It is constructed of oak, well bound with stout iron hoops, and covered tightly. In the centre of the tun a shaft, A, to which a bevelled cog-wheel, gearing into another fixed on the main shaft from a steam-engine, but which is not shown in the drawing, is appended. In the interior of the tun four brass arms, *d*, studded with large teeth, extend from the shaft, turning round with the motion of the axis, and keeping the contents in brisk agitation.

Fig. 4.



Heat is communicated by means of a convoluted steam-pipe placed at the bottom, and perforated with small holes. This pipe is furnished with a stopcock, for the purpose of shutting off the steam, or otherwise regulating it.

In this tun, the hydrate of lime is mixed with the fat in the proportion of 15 per cent. of its weight, the lime being made into a moderately thick cream with water—1¼ gallon to 1 lb. of lime. Care should be taken to have the caustic lime as pure as possible: if it be not properly caustic, an increased amount of acid will be required to neutralize it. When there are many impurities in the lime these are with difficulty separated from the mixed acids afterwards. Having thoroughly blended the cream of lime with the tallow in the decomposing tun, the cover of which is fastened down tightly, the steam is turned on and allowed to play upon the contents for six hours, keeping the whole constantly agitated by the aid of the rotating stirrers provided for this purpose; at the end of that time the combination of the fatty acids with the lime is generally complete. The test by which the workman can judge whether the sap-

onification is perfect is to take out a small portion of the thick mass, and allow it to deposit the insoluble lime soap; the supernatant water is then poured off, and the subsided matter cooled; if this mass appears smooth, homogeneous, and semitransparent throughout, makes a sharp noise on being fractured, and goes into powder on being ground in a mortar, there remains no undecomposed fat. The steaming in the vessel should be continued till the contents give these reactions. The steam is then shut off, and a quantity of cold water gradually added, keeping the machinery in motion during the time. This drenching with cold water causes the insoluble soap to assume a granular appearance, and take up the glycerin, and as soon as this is effected the agitation is discontinued. When, after a short interval, the whole has settled, the water, together with the glycerin of the fat, is drawn off by means of a plug hole at the bottom of the tun, protected on the inside by a sheet of fine copper, wire gauze, or cloth, so that the small particles of lime soap cannot pass out when the plug is removed. As soon as the whole of the water has run off, the outlet is stopped up, and more cold water poured upon the soap, and the mixture agitated; this is drawn off as before.

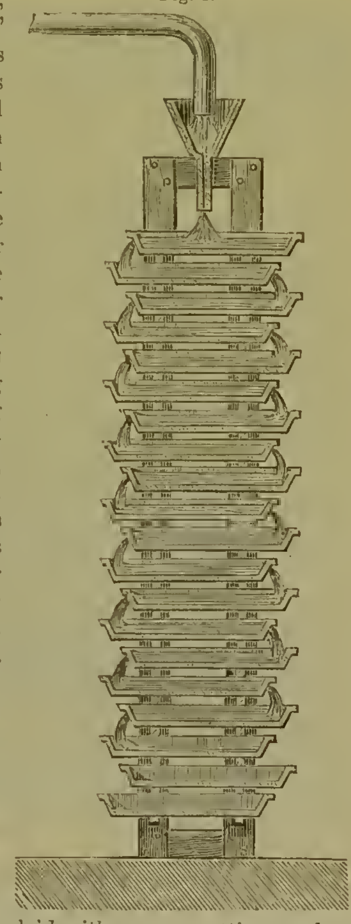
By such repeated washings the whole of the glycerin is removed, and nothing remains but the lime compounds with the stearic, palmitic, and oleic acids of the fat, together with the slight excess of lime which may have been taken to insure complete decomposition.

The next stage in the operations is the decomposition of the soaps and the removal of the lime. This is done by the addition of concentrated sulphuric acid, in the proportion of 250 lbs. of acid, diluted with 2000 lbs. of water to every 1000 lbs. of fat saponified. The dilute acid is gradually poured into the tun upon the soap, the mixture being heated by the steam coil to about 200° Fahr. (93°·3 C.), but no higher, and the whole is gently agitated till the decomposition is complete—a point ascertained by the disappearance of its granular structure as well as by the fatty bodies rising to the surface.

Much care is necessary on the part of the attendant during this period, in regulating the entrance of the steam, for if the temperature becomes too high, with the presence of a strong acid and exposure to air, the colour of the products will be injured. The tun may be left uncovered during the decomposition without any disadvantage arising. When the separation of the lime is complete, the contents of the tun are left to rest for some time, in order that the sulphate of lime may be entirely taken up by the water, and removed from the fats which occupy the upper strata. The plug hole at the bottom of the tun is then opened, and the solution of sulphate of lime, with any other lime salts or caustic lime that may be held mechanically in the liquid, is drawn off. Hot water is then let in, and the agitator set in motion; the warm water melts the fats, and the separation of any saline matter or excess of lime is facilitated. After the melting and agitation has been continued for some time, the contents are allowed to repose as before, and after the water and any impurities have settled to the bottom, they are drawn off through the outlet. The washing is continued till the last traces of the mineral compounds are separated, and then the crude fatty acids reheated to the melting point, and drawn off into casks or trays to crystallize.

The trays employed are made of tin, and have a capacity varying from 16 to 20 inches in length, 10 to 15 in breadth, and 2 to 3 inches deep; after being charged with the melted fatty bodies, they are ranged upon convenient shelves in an appropriate room, the temperature of which stands between 70° and 90° Fahr. (21°·1 to 32°·2 C.); here they remain for two, three, or more days, till the stearic and palmitic acids, &c., assume a crystalline form, or "granulate." Oleic acid does not solidify at this temperature, and at the termination of the granulation it may be observed upon the solidified matter on the trays in the form of drops or exudations. A very ingenious method of filling the granulating trays, the invention of M. Binet, is shown at Fig. 5.

Fig. 5.



When the mass in the tin tray has crystallized or granulated as far as possible, it is removed to a machine, where it is cut into thin slices by a knife attached to a revolving wheel, against which the fatty matter is pressed. The sheets of fatty acids are then interlaid with coarse matting made of jute or cocoa-nut fibre, or each of the cakes may be at once enveloped in a canvas or woollen bag, and placed under a hydraulic press, and the chief part of the oleic acid expressed.

When placing in the press the sheets of fat interposed with matting, or enveloped, as the case may be, in coarse bags, plates of wrought iron, with turned up rims, are put in between the cloths at regular intervals till the frame is filled; the sheet-iron plates prevent the whole mass from being blended too tightly together by the great pressure, and in the channels formed by the rims the oleic acid is collected.

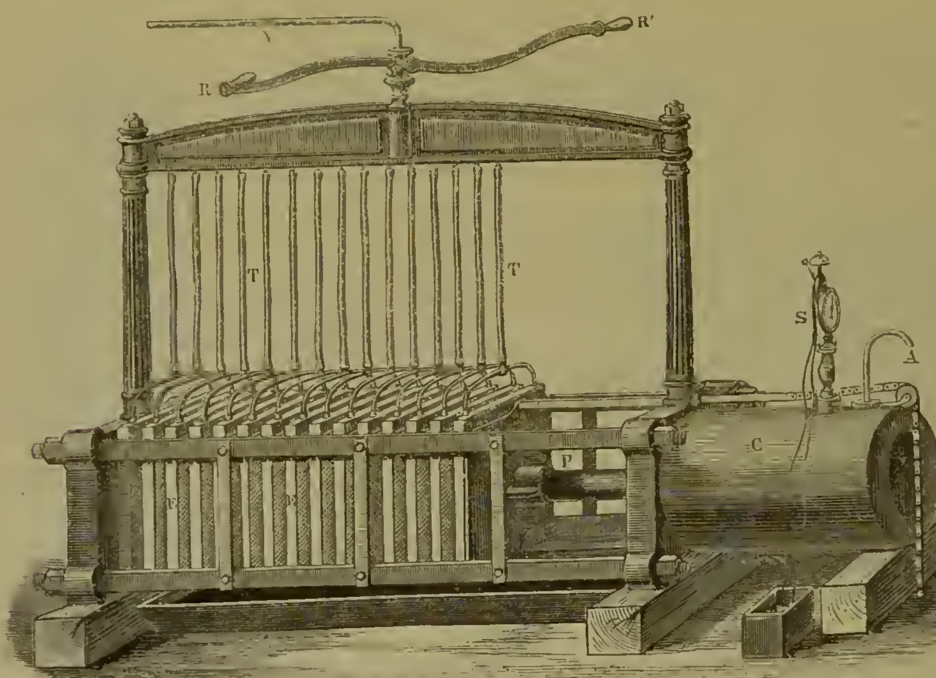
After the pumps have been set working, and the

pressure has been exerted till no more fluid exudes, the machine is loosened and the expressed layers taken out. The fat, by means of this compression, becomes so dense and hard as to be scarcely marked by the nail. The cakes, however, still retain oleic and palmitic acids, to abstract which they are usually submitted to a second compression, under the influence of heat, particularly when the products are required for the best kinds of stearic acid candles. The cakes are inclosed first in canvas or woollen bags, and afterwards coarser ones, made of cocoa-nut or jute fibre, and placed between iron plates surrounded by hollow frames.

The form of press used is shown in Fig. 6. A is the tube by which water is forced into the cylinder, C, containing the hydraulic piston. A pressure gauge, S, indicates the degree of compression. P is the piston; E E, iron frames surrounding the bags containing the cakes of crude fatty acids, and which are heated by steam. The steam enters the press by the pipe, V, on opening the valve controlled by the lever, R R′, and descends the tubes, T, which are furnished with joints allowing the frames to move to and fro. After a sufficient amount of pressure the fat is taken out, and may be at once used for candle making. It then constitutes the mixture of stearic and palmitic acids known as stearin.

If any further purification is desired, the pressed cakes of fat are introduced into a large covered tub constructed of wood, and bound firmly with strong iron hoops; into this vessel steam is forced during five or six hours; it is then shut off, and when suf-

Fig. 6.



ficient time has elapsed for the water to fall to the bottom, the layer of fatty acids is conducted into moulds and cooled.

In some factories the whole process is conducted by hand. The tallow is placed in large open wooden vats lined with lead, and heated by direct injection of steam through copper pipes. When the fat is melted, milk of lime is added in the proportion of 14 to 15 parts of lime to 100 of tallow. The mixture is kept boiling for eight hours, being agitated from time to time with a wooden paddle.

Steam is then shut off, and the decomposition effected by means of sulphuric acid, the lime soap being allowed to settle, and the sulphate of lime solution run off, as before described. Fig. 7 shows the general arrangement of the plant, the vats being so arranged that the process may be constantly going on at different stages. When the decomposition is complete the whole mixture is left till the next day, when the still liquid fatty acids are removed by a syphon to the washing vats.

To De Milly much of the present prosperity of the candle-making trade is due. He was the first to overcome the difficulty arising from crystallization of the stearic acid in the candles by adding a small quantity of wax, thus rendering the candles homogeneous; though of late years solid paraffin has been substituted for the wax, with even better results. To him also is due the idea of saponification by lime instead of soda (thus lowering the cost of the process very materially): also, the complete expression of the oleic acid by the horizontal hydraulic press, aided by heat: and lastly, the employment of boracic acid in the preparation of the wicks, the mode now universally in use to check the too rapid combustion of the cotton.

He has recently reduced the amount of lime used for the saponification. In place of 14 to 15 per cent.

of lime, he now uses only from 2 to 4 per cent. This great reduction he effects by heating the milk of lime and fat to 341°·6 Fahr. (172° C.) by steam of 150 lbs. pressure, which has the temperature of 359°·6 Fahr. (182° C.)

Tallow treated in this way in a steam boiler with 2 per cent. of lime is completely saponified in seven hours. On withdrawing the contents of the boiler, the mixture is found to be an aqueous solution of glycerine, free fatty acids, and a small quantity of a lime soap. This method of saponification is very profitable, in consequence of so much less sulphuric acid being necessary for the decomposition of the lime soap. The lime soap is also much more easy to deal with on account of its comparative fluidity, since it can be at once run off into the decomposing vat.

Several explanations have been given of this mode of working; the most reasonable appears to be that of Wright and Fouché, who show that water is by itself at a high temperature capable of causing the dissociation of fats and oils into glycerine and fatty acids. A process which was long successfully in use (Tilghmann's), in which the use of lime was entirely dispensed with, depended on this fact.

Sulphuric Acid Process.—In 1777 Achard discovered that neutral fats were decomposed by concentrated sulphuric acid. In 1821, when the true nature of fats was shown by Chevreul, Cavendish

Fig. 7.

ton drew attention to Achard's experiments, pointing out the analogy between the action of sulphuric acid and the alkalies on fatty bodies. The fatty acids set free by the sulphuric acid are, however, mixed with carbonaceous matter which cannot be separated by chemical means. It has, however, been found, that if the black mixture is submitted to distillation with the help of a jet of steam, the fatty acids are carried over by the aqueous vapours, and stearic, palmitic, and oleic acids, together with glycerin, are obtained in the condenser free from colour and almost inodorous.

George Gwynne, in 1840, patented a process for the manufacture of stearic acid by treatment with sulphuric acid and subsequent distillation by means of a vacuum pan similar to that used in sugar refining.

In 1841 Dubrunfaut really solved the question of distillation by assisting the volatilization of the fatty acids by means of a current of steam rushing through the black quagma. He, however, omitted the previous reaction with sulphuric acid, which is essential to success.

In 1842 Price & Co. (really Messrs. Jones & Wilson) took out a patent for the distillation of fats previously acted on by sulphuric acid or by nitrous gases. In a lecture to the Society of Arts Mr. G. F. Wilson says:—"While Jones and I were experimenting under this patent in one part of our works, Mr. George Gwynne was at work in another, with a small silver retort connected with an air pump. His object was our carrying out on a large scale his patent of 1840; but finding that steam excluded

the air as effectually as the air pump, we combined our forces, and in 1843 took out two patents for improvements in the processes and apparatus, under which part of our manufacture is still carried on."

The sulphuric acid process is available for palm oil, cocoa-nut oil, bone and marrow fat, kitchen stuff; indeed, the solid fatty acids of almost any kind of fat can be profitably extracted by this mode of working, or one of its modifications.

Fig. 8 represents a form of apparatus which is sometimes used. A is a wooden vat, lined with lead, and containing the sulphuric acid, which is maintained at the temperature of 194° Fahr. (90° C.), by a steam coil. B is a lead-lined vat, containing the fat to be operated on, which is likewise kept at the temperature of 194° Fahr. (90° C.), by a steam coil. The tank, F, in which the reaction is completed, is placed beneath the melting vat, B. The workman commences by filling the vessel, D, from the reservoir, B, with a known weight, say 1 cwt., of melted fat, by opening the tap, G, and the leaden trough, C, with the same weight of sulphuric acid (30 p. 100), by opening the tap of the acid reservoir. He then empties the vessel, D, into the trough, C, and agitates the whole rapidly by means of a rake. A brisk reaction takes place, and the mixture becomes black. At the end of about a minute the trough, which is suspended on an axle, is turned over, and throws the acid and fat into the tank, F, which is full of water, kept boiling by a steam jet. The sulpho-fatty acids are quickly decomposed by the boiling water into free acids and glycerin.

Fig. 8.

After a time the liquid separates into two layers. The lower, H', is water charged with sulphuric acid and glycerin; the upper, H, consists of stearic, palmitic, and oleic acids. The acid water and glycerine is first drawn off by the tap, E, placed at a convenient height, and then the fatty acids are run into another vat and thoroughly washed with hot water.

The fatty acids are still black and charged with many impurities from the foreign matters contained in the fats. The carbon and the impurities are alike removed by distillation.

Great advantage is gained in point of time by superheating the steam before passing it into the still, that is to say, by raising its temperature to about 482° Fahr. (250° C.), in place of 212° Fahr. (100° C.). This is effected by carrying the steam through coiled pipes heated in a suitable furnace. Fig. 9 represents the arrangement of the plant. B is a copper still containing the fatty acids; it is closed in by a dome provided with a man-hole, C. The supply of fatty acids is kept hot in the reservoir, A, placed above the furnace, H; they run into the still, B, through the tube, D D, on the tap, S, being opened. The still is kept hot by the fire, and also by being closed in at the top by a bed of sand in an earthenware pan which acts as an exterior lid. The still is provided with a thermometer, the stem of which projects outside it. As soon as this indicates the temperature of 482° Fahr. (250° C.), steam is admitted by opening the tap, R. Care must be taken that the temperature of the steam is 482° to 572° Fahr. (250° to 300° C.). The furnace, H, is used to

heat a boiler, the steam from which is superheated by being made to pass through the heated coils, M and N; a thermometer is placed upon a bend of the steam pipe, near the tap, R. Under these conditions the fatty acids are volatilized in company, and carried forward with the superheated steam, and pass by the tube, E, into the receiver, G. This vessel (G) is a sort of first condenser. On opening the tap, L, with which it is provided, the first portions of the distillate are collected. These consist for the most part of sulphuric acid, acroleine, and like matters.

The vapours of the glycerin, and stearic, palmitic, and oleic acids, still mixed with steam, traverse the double coil, K (which is cooled by a continuous current of water passing through its exterior), are condensed and collected as liquids at the outlet of the tube, U. On flowing into the receiver the fatty acids rise, and are drawn off by the tap, V, whilst the water and glycerin go to the bottom, and are removed by the tap, X.

A brown fluid residue remains in the still; this is drawn off by a small pump, Y, at the lower part of the still. On cooling this residue concretes and becomes a hard black mass resembling asphalte. The residue of the distillation is 6 to 7 per cent. of the whole amount distilled.

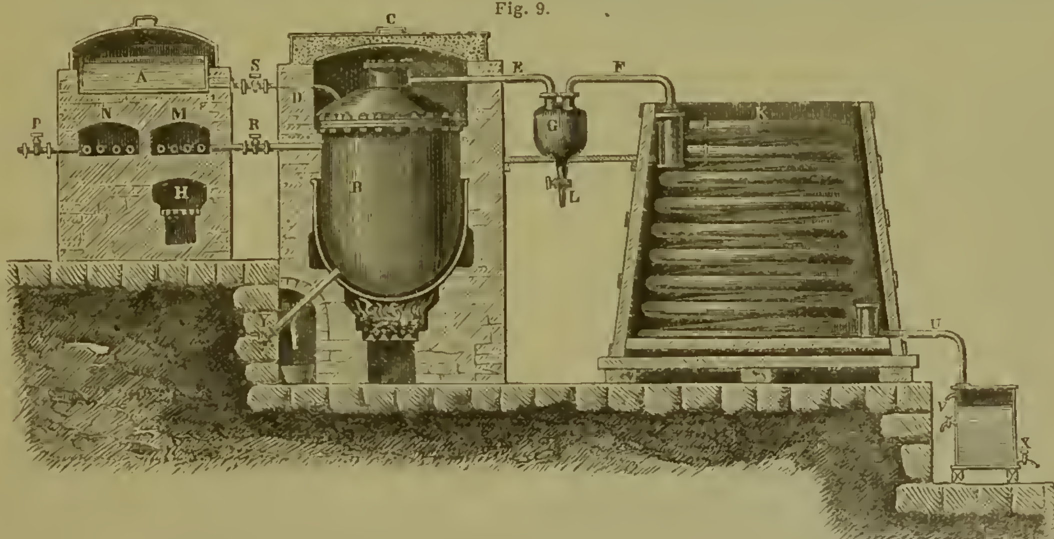
The distillation occupies from twelve to fifteen hours, when the still is charged with 25 cwts. of sulpho-fatty acids.

The quantity of fatty acids obtained by this process are from palm oil 75 per cent., which on pressure yield 50 per cent. of solid stearic and palmitic acids. From tallow 60 per cent. of solid fatty acids are obtained. Saponification by lime only yields 45 per cent.

PALMITIC ACID.—In the works of PRICE'S PATENT CANDLE COMPANY palm oil is subjected to saponification and distillation to extract the palmitic and stearic acids by much the same process.

About 20 tons of palm oil are fused by steam

Fig. 9.



in a large wooden vat lined with lead, and after it has settled this is pumped into an acidifying vessel, where it is heated by steam to about 350° Fahr. The steam is generated in the usual low pressure boiler, but the pipes through which it passes to the acidifying vessel are heated in a furnace, and thus it acquires a higher temperature. Concentrated sulphuric acid, in the proportion of 6 lbs. to the cwt. of the oil taken, is now gradually added. This is done by means of a leaden pipe extending across the boiler or tank, perforated with holes at the sides at a distance of 6 inches. The acid thus introduced equally over the mass causes violent ebullition throughout, by which the sulphuric acid and the palm oil are intimately mixed, even before any signs of decomposition are manifest. After a further heating of the mixture for an hour or more, it is allowed to rest for six hours. It is now of a blackish colour, and is pumped out to a vessel containing water slightly acidulated with sulphuric acid, and heated by blowing steam through it for two hours; it is then left at rest for twenty-four hours longer, after which time the water is removed. Both these vessels are well covered, and the vapours given off from them during the boiling are conducted by an exit pipe into the chimney.

After washing the fat, it is melted and raised by pumps to a tank commanding the stills; the latter are made of copper, and heated partly by an open grate fire, and partly by steam. A charge of the decomposed and washed fat, consisting of about 5 tons, is introduced into these vessels, and heat applied till it reaches about 560° Fahr., when low-pressure steam, raised to a higher degree of heat, is conducted into the mass, the air being excluded all the time. In order that the whole of the inclosed materials may be heated equally and regularly, the steam issues from numerous holes in a pipe convoluted on the bottom of the still, not unlike that of a sugar-house vacuum pan; and in this way the volatile constituents are more readily carried off to the condenser, together with the steam. The mixed vapours from the fatty acids and water are conducted

to a series of vertical pipes, the temperature of which exceeds 212° Fahr., and in passing through them the fatty matter is almost wholly condensed, while the steam flows off to a refrigerator, where it meets with a current of cold water, and is condensed, together with any minute portions of the fatty acids that might have escaped. These are collected in a tank, whence the water is drawn off at the bottom, while the fat floating on the surface remains.

After a considerable portion of the charge has been driven over, the residuary matter in the still is drawn off, and introduced into iron pipes raised to a higher degree than the still, by being placed in a furnace; a jet of superheated steam is passed over it, by which the fatty acids are carried forward, atmospheric air being still excluded. By these means an additional quantity of fatty matters is obtained, while the substance remaining in the pipes, after the distillation is exhausted, is applied to the same uses as ordinary pitch.

The mixed fatty acids proceeding from these distillations solidifies into a tolerably compact mass, and is used to a large extent for making the "composite" candles without being pressed; but these are nevertheless much inferior in melting point and durability to those made from the purified material.

To prepare the distilled palmitic and stearic acids for pressing, they are cut into shreds of a convenient size by a revolving cutter worked by an endless strap attached to a shaft from the steam-engine. The pieces lopped off at each revolution are conducted by a sliding tube to a carriage, where the slices as they fall are spread by the workmen upon cocoa-fibre mats in layers of equal thickness, regulated by an iron frame. Each layer of material is covered with another mat, and when the pile has become sufficiently large, it is carried off to the pressing-room. After the greater part of the oleic acid has been extracted, the cakes, after fusion and granulation, as before explained, are further expressed in horizontal hot-presses (see page 438), kept at a temperature of 85° or 90° Fahr. by means of steam.

After the pressing has been performed, the mattings are removed from the layers of fatty acids; these are divested of the yet oleaginous edges by paring, and are then brought to the steaming or boiling house, where they undergo another fusion with water acidulated with sulphuric acid, in large wooden iron-bound tuns, heated by steam pipes branching into them from a main connected with the steam boiler. Having been kept seething for some time, the whole is allowed to repose, and the acid water, after subsidence, drawn off; the fat is then washed with fresh quantities of hot water to remove all extraneous matter, and when this is accomplished, it is run into moulds or blocks. The material is at this stage sufficiently pure and hard to be manufactured into candles.

MANUFACTURE OF CANDLE WICKS.—The wick of tallow candles is formed of fine threads of cotton twisted, or otherwise bound together, though occasionally flax fibre and many other substances are employed; the former, however, answers best. For dip candles nothing answers so well as Turkish cotton rovings. The desirable qualities of wicks are, that they should burn freely and completely, leaving only a small quantity of a light ash, and must be good absorbents. The form of the wick varies according to the quality or composition of the candle; generally, they are composed of a number of threads, of greater or less fineness, twisted loosely or plaited together. No inequalities should exist, either in the shape of knots or adhering particles of cotton, as otherwise the candles would gutter. Again, the finer the threads composing the wicks, the more perfect will be the combustion of the melted fat.

For stearin and paraffin candles the wick is plaited over a braiding machine, and dipped in a solution of boracic acid before using. It thus twists out of the flame and is completely burnt away, so that snuffing is not required.

Some years back wicks which did not require snuffing were constructed by attaching to the plaits of cotton, by gimping, strings or threads of some fibrous material, with the intention that as the fat was consumed a bend should be given to the wick, which should carry its tip into the oxidizing part of the flame, and so insure its complete combustion. At the present time, by simply arranging the plait in such a way that one thread is shorter than the other the same effect is secured.

The wicks are then dried and soaked in a mixture, made by dissolving an ammoniacal or other alkaline borate, or nitrate of bismuth, in water. It has also been recommended to dip the wicks in a solution consisting of 3 quarts of water, 2 ounces of borax, 1 ounce of chloride of potassium, 1 of nitrate of potassium, and 1 of chloride of ammonium, taking care that they are thoroughly dried as well before as after the immersion. A solution of boracic acid is the dipping liquid now most used. The purpose in each case is to cause the fusion of the ash of the cotton and to retard the combustion.

To give a larger illuminating surface to the flame, some manufacturers use a double wick plaited, with the strands running from the centre upwards to the edges, and turning contrary ways, so that both ends will incline outward at the point of combustion, thus enlarging the extent of flame, and of course proportionally increasing the light.

The labour of preparing the wicks in large factories is considerably lessened by the use of machinery. Fig. 10 represents a plan of a machine for cutting and suspending the wicks for "dip" candles. Fig. 11 is a sectional elevation of the same: A A is the frame; B a grooved roller, over which the cords of twisted or plaited cotton are passed from the bobbins, I I; C is the clip or holder, seen in a front elevation in Fig. 12, and consists of two principal pieces or bars, *a* and *b*, held together by means of two sliding clamps, *c c*. D and E are the blades of the scissors; the former is fixed and the latter movable. F is a trough in which the liquid fat which is used as a cement to retain the wicks upon the rod, H, is contained. The fat is kept liquid by means of a jacket, which is surrounded by hot water, steam, or heated

air. H is the square rod or "broach," upon which the wicks are fixed and supported during the time they are immersed in the frame resting upon the table G.

The following is the manner in which this apparatus is worked:—The cords being prepared on suitable bobbins are brought down through the roller, B, and secured between *a* and *b* of the clip or roller, C, each cord being left to project 1 inch in advance of the front edge of the clip. The bars, *a* and *b*, are made to lay firm hold of the cords by moving the clamps, *c c*, which bring them together in consequence of

Fig. 10.

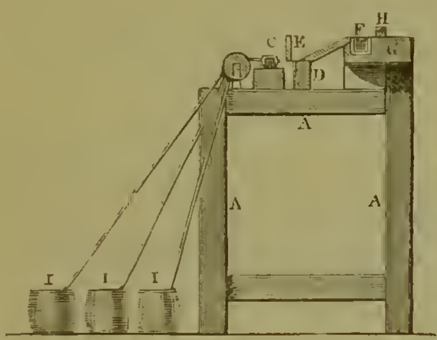


Fig. 11.

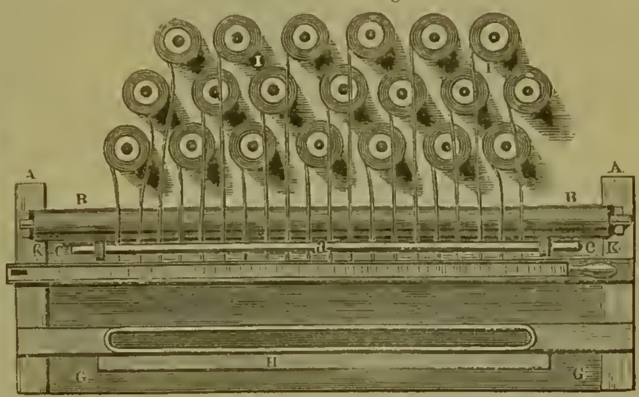


Fig. 12.

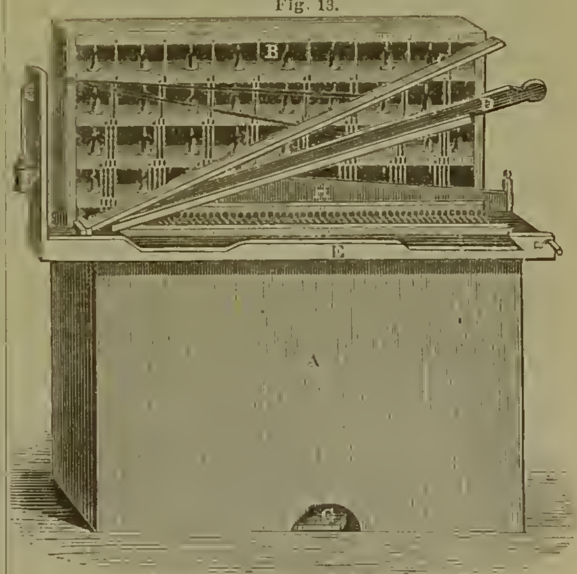
the wedge-shaped form of the upper bar, *a*. The cords being thus secured, the clip is lifted up and drawn forward by the workman, after which the free ends of the cotton that are left protruding from it are immersed in or brushed over with the fatty cement contained in F, and then laid on the top side of the square broach or suspending rod, H, and are made to adhere to it with sufficient firmness to sustain them during the process of dipping by a slight pressure. Next, the clip is slackened by moving the clamps, *c c*, outwards; they are then pushed forth over the cotton towards the bobbins till the length to be cut for the candle is gained, when, by reversing the movement of the clamps, *c c*, the cords are again tightly laid hold on; and finally the clip is rested upon the table, G, which is about 1 inch from the cutting apparatus. The movable blade, E, of the cutter is brought down, and the set of wicks of the proper length cut off, leaving as much of the cotton adhering to the end next the suspending rod as will support the next batch as before. The rod, H, with the wick adhering to it, is placed in a dipping frame, and another rod again loaded with wicks as before, and so on till the frame is full.

The bars of the clip, C, may be hinged, so that when opened they will allow the bundle of yarn or cotton to pass freely; but when closed they will take a firm hold of them, as shown in the cross section, Fig. 12.

Another machine in extensive use in America is the following. It is said to cut, spread, and twist as much wick in an hour, with the attendance of one man, as will suffice for 1000 lbs. of candles.

Fig. 13 is a drawing of the apparatus. A is the body of the machine, inclosing the pulleys and other appendages that regulate the movement of the carriage, B, which is set in operation by the treadle, G. The carriage, B, rests upon the body; it is a kind of

Fig. 13.



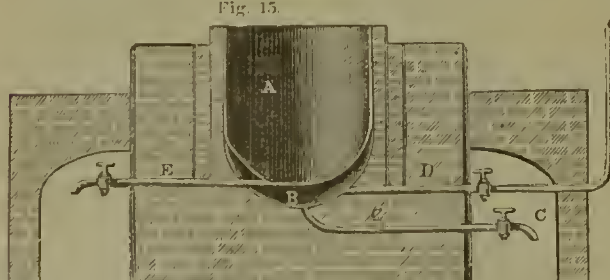
framework running on wheels, and containing a number of boxes placed shelfwise, and serving as receptacles for balls of cotton wick, the ends of which run through a notched reed, below H; it comes forward upon the twisting board, E, at the back of which a knife, H, is fastened, that serves as

the under blade of the clipper, D. This, when drawn down vertically, severs the wicks evenly. The twisting-box, E C, consists of two boards hinged, and moving on rollers. A turn of the crank near the end communicates the motion which twists the wicks after they have been cut by the knife, D, and this knife having effected its purpose is immediately

Fig. 14.

drawn up by a counterpoise, F. At the front of the twisting-box, D, a sliding-box is so fixed that it can be graduated to regulate the required length of the wicks. Motion being communicated to the machine, the yarn is then cut, spread, and arranged on the rods simultaneously, and in complete readiness for

Fig. 15.



dipping: as soon as the workman removes it another rod rolls into its place, and thus the work proceeds till the wick or rods are expended, when, as a matter of course, a fresh supply must be provided.

Fig. 14 shows another machine for cutting the wicks; *a* is a box in which the balls of cotton are placed. The ends of the wicks are drawn over the bridge, *b*, above which the rods, *c c*, are introduced, and as the workman fills each rod he brings others forward by means of the treadles, *h i*; *d* is a hand-board which keeps the wicks in their place while they are being cut by the knife, *e*. Both knife and board are lifted up, after the wicks are cut, by counterpoises, *g g*, attached to them by cords passing over small pulleys. The length of the wick is regulated by the screw, *f*, in front of the workman.

DIP CANDLES.—Candles are made either by "dipping" or "moulding." In the former process the prepared wicks are repeatedly immersed in a bath of melted tallow, till a sufficient quantity has adhered to them: the finished candles are known as "dips;" and in the latter, the wicks are placed in pewter moulds, and the melted fat poured in and allowed to cool; in this case they are termed "moulds," or moulded candles.

It may be here mentioned that in this country, at any rate, the manufacture of dip candles is rapidly dying out. "Dips" are invariably made of tallow.

The tallow is clarified by remelting it with about 5 per cent. of water in a copper pan, fitted with a steam-jacket (Fig. 15).

A represents the copper pan inclosed in a jacket, B, and supported on brickwork or masonry. A stopcocked pipe, E, opens into the bottom of A, and two others, C and D, communicate with the interior of the lesser one at the bottom and side. Into the vacant space between the walls of the tanks, steam is injected through the pipe, D, which is furnished with a stopcock for turning it off when desirable; the jacket should be supplied with a steam-gauge to notify the pressure of steam upon it.

Instead of this arrangement the pan may have a jacket carried completely to the top, be supported on a pedestal of brickwork, and be surrounded with a felt casing, to hinder dissipation of heat by radiation.

In Fig. 16, P is the copper-melting vessel surrounded by a jacket J (which may be of iron), outside which is a casing of felt, F, the steam (5 lbs. pressure is sufficient), enters at S, and is carried by a copper coil, C C C, round the pan to the bottom of the jacket, where it passes into the jacket itself, G is the steam-gauge, T the tap for drawing off the tallow, and W, that for the condensed water. Before turning on the steam the small tap, E, must be opened to allow the air to escape; it is closed when the jacket is filled with steam.

The fat, after being minced, is thrown into the pan, with some water, and the whole is melted by the circulating steam. When sufficiently fluid, it is drawn off into another vessel, where, after it has settled, the superior fat is drawn off from above the water into another tank, and the residuary matter expressed. Frequently the casks of tallow, after being unheaded, are inverted over the pan, and emptied into it by directing a jet of steam into them.

A little indigo ground in oil is sometimes added to neutralize the yellow cast of the tallow; and instead of water, lime or solution of alum, ammonium chlor-

ide, saltpetre, and other salts, are used by some melters. By adding 7 parts of sugar of lead, dissolved in a little water, to each 1000 parts of tallow, and agitating thoroughly, the tallow is made much harder.

The mode of making dips is very simple. The tallow is poured into a trough made of stout walnut or cherry boards firmly put together and resting on a pedestal or other support 2 feet high; this trough is lined with lead, and on the side on which the workman stands is a thick board, the same length as the trough, fixed in a slanting position, to tap the candles on, and thus to detach the superfluous tallow from their ends.

By the side of the dipping trough, and to the left of the workman, is the reservoir of melted fat—*c c*, Fig. 17—kept properly fluid by a steam jacket; or the same may be effected by renewing the hot tallow at regular intervals. On the right hand is fixed a long upright side frame, under which is a tray, made of boards, which may be lined with lead, of the same size as the frame, and with its sides inclined outwards, to collect the droppings which fall from the wicks on their removal from the bath. Above the bath is a beam to which the workman, when the rods of candles become too heavy for him, attaches them, at the same time balancing them by the metallic slide on the lever end of the beam—the dipping is thus facilitated. This arrangement is shown in Fig. 17.

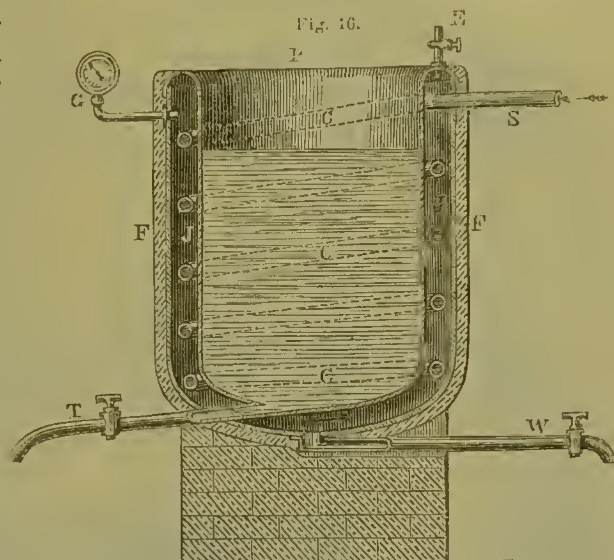
Thin wooden rods about 2½ feet long are fitted with wicks, ten on each rod.

Having supplied all the rods with wicks, the workman brings them to the frame at the back of the trough, and the dipper takes six or eight at a time upon the small frame, *e*, which he holds in his hand, shown in the annexed Fig. 17, and by an expert movement introduces the dry wicks into the molten tallow, *a*; when they are completely saturated he withdraws them, and by a dexterous shake, whilst the ends of the wicks are yet in the fluid, separates any which may have stuck together.

To facilitate this operation, the tallow is brought into a more fluid state than at subsequent dippings. When the wicks are charged with the tallow, they are laid on a longitudinal frame to the right of the operator, and fresh rods are proceeded with in the same way, till the whole of the wicks are immersed, the bath being kept full of melted tallow during the time.

The second dipping is performed in the same way as the first, except that it takes less time; the bath of tallow is also colder, in order that more tallow may be taken up by the wicks. It is held to be of a proper consistency when the tallow in contact with the sides of the trough is observed to solidify. In this and the several succeeding dippings, it is necessary to retain the lower part of the candle a little

Fig. 16.



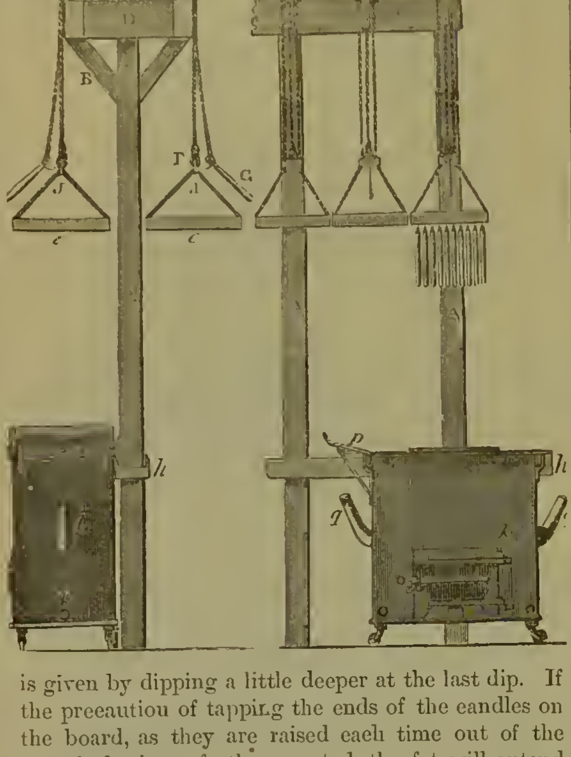
longer in the melted tallow than the upper, to prevent the bottom of the candles being too thick. The ends of the candles should be tapped upon the board, *b*, on their withdrawal from the bath, to detach the small pellicle that drops down, but which solidifies

Fig. 17.

before it falls. After several dippings the candles become heavy, and the frame, which hitherto has been held in the hand, is hooked upon the beam, *d*, and counterpoised with the weight the candle

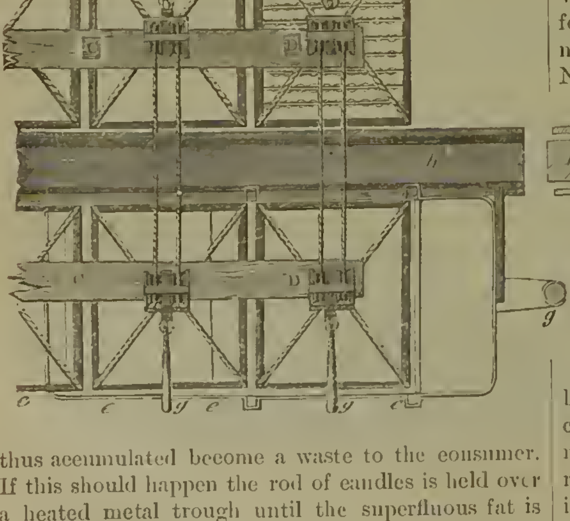
are desired to have when finished. The final dippings must be performed with care and skill, to communicate a proper cylindrical smooth appearance. The conical spire at the top of the candles

Fig 18.



is given by dipping a little deeper at the last dip. If the precaution of tapping the ends of the candles on the board, as they are raised each time out of the trough, be imperfectly executed, the fat will extend half an inch or more below the wicks, and the tallow

Fig. 19.



thus accumulated become a waste to the consumer. If this should happen the rod of candles is held over a heated metal trough until the superfluous fat is removed.

Figs. 18 and 19 show a form of apparatus, by which many candles can be dipped in succession with ease and regularity. The frame consists of five oak-wood beams, A, each bearing near its top two abutments, B (seen in the end view, Fig. 18), connected together by the long cross pieces of horizontal frame, C, throughout the length of which are five small traverses, wherein the beams or posts, A, of the frame are mortised. The iron caps, D, are fixed upon the sides of the long cross pieces of the frame, C, and each has two brass pulleys. The fastening or connection of these caps is effected by stout screws inserted in the beam, C. Each pulley receives a cord, F, at the extremity of which is a small wooden frame of a rectangular form, and grooved at the sides interiorly, for the purpose of supporting the broaches or rods on which the wicks are suspended. The wooden handles, G, have each a hook fastened in a hole in the centre of a small rectangular iron plate, J, to which are attached the cords of the pulley and rectangular frame, *e*. The long traverse, or cross piece, *h*, is grooved on each side, to guide the movement of the furnace. This arrangement of the pulleys, and the guiding of the beam, *h*, are shown in the vertical view (Fig. 18), where the arm of the furnace fits into the grooving, along which it runs as the latter is pushed round the machine. The furnace moves on four castors. It has two doors for the purpose of introducing a small tray of red-hot coals, to keep the tallow at the right temperature for dipping. Dampers are used to regulate the combustion of the coals. There are two baths, one inserted in the other. The larger is filled with water and kept at a temperature of 85° to 95° Fahr., and by contact of the liquid heated to this degree the smaller bath of material will have acquired a temperature of 50° to 60° Fahr., and by this means the adhesion of the stuff is expedited. To catch the drippings from the candles, on being made to emerge from the bath, a plate is fixed to the exterior of the tank, inclining inwards, so that any of the fat that falls upon this plate is returned to the bath without waste. When this machine is worked the two receptacles for the tallow are filled, and then heated to the necessary temperature by the fire beneath them. Next, the furnace is pushed forward under the frame

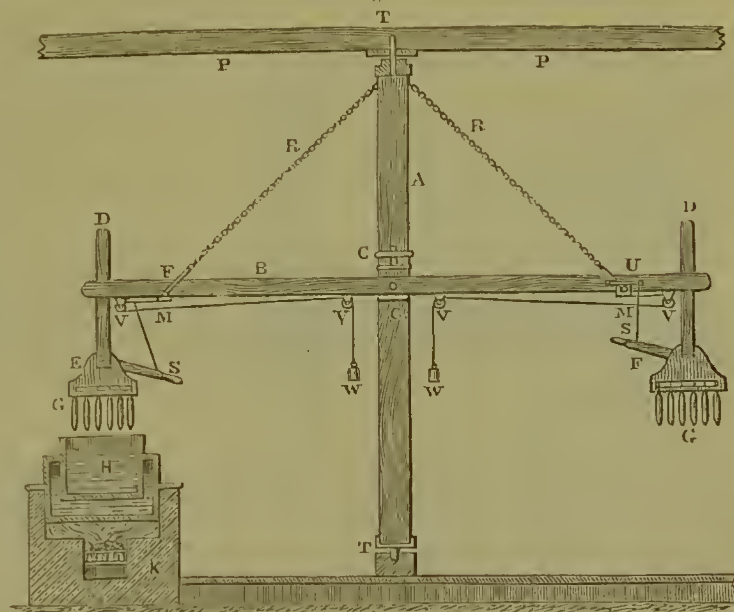
c, on which the rods, loaded with the wicks, are supported; this frame is depressed by the hand, and the wicks immersed repeatedly in the fat till the candles have become sufficiently large, and then the frame is raised to a higher elevation, and so retained by hooking the handle, G, to the plate, J, as before described.

The furnace is then removed to the next frame, and the dipping proceeded with as before, and so on till the frames are worked off.

The candle-dipping machine, known as the Edinburgh wheel, is exceedingly convenient to use, as it can be worked by one man. Fig. 20 shows the machine as it stands in the middle of the dipping-room. A A is a strong upright post turning upon iron axes, which are inserted into the socket T and into the beam P P. It is thus free to rotate. Near the middle of the upright A six mortises are cut at

small distances from one another, and crossing each other at an angle of 60°; into each of these mortises is inserted a long bar of wood, B, which moves vertically upon an iron pin, C, passing through the middle of the shaft. The whole presents the appearance of a large horizontal wheel with twelve arms, of which, however, only two are seen in the figure. From the extremity of each arm is suspended a frame, E (or *port*, as the workmen call it), containing six rods, on each of which are hung eighteen wicks, making the whole number upon the wheel 1296. The machine, though apparently heavy, turns round by the smallest effort of the workman, and each "port" as it comes in succession over the dipping mould, H, which is placed in a water bath mounted on the furnace, K, is gently pressed downwards by the handle, S; by these means the wicks are regularly immersed in the melted tallow. As the arms of the levers are all of the same length, and as each is loaded with nearly the same weight, it is obvious that they will all naturally assume a horizontal position. In order, however, to prevent any oscillation in the machine in turning round, the levers are kept in a horizontal position by means of small chains, R R, one end of which is fixed to the end of the top of the upright shaft, and the other terminates in a small square piece of wood, M, which exactly fills the notch, F, in the lever. As one end of the levers must be depressed at each dip, the square piece of wood is thrown out of the notch by the workman pressing down the handle, S, which communicates with a small lever inserted into a groove in the bar, B. In order that the square piece of wood, M, fixed in the extremity of the chain may recover its position upon the workman's raising the port, a small cord regulated by the weight, W, is attached to it, which passes over the pulley, V, and again over the second pulley, V, and draws the block, M, forward to the notch. In this way the operation of dipping may be conducted by a single workman with perfect ease and regularity. No time is lost, and no unnecessary labour is expended in removing the ports after each dip; and the process of cooling is much accelerated by the candles being kept in constant motion through the air. The number of revolutions which the wheel must make in order to complete one operation, must obviously depend upon the state of the weather and the size of the candles; but in moderately cold weather, not more than two hours are necessary for a single person to finish one wheel of candles of a common size. Upon the supposition that six wheels are completed in one day, no less a number than 7776 candles will be manufactured in that space of time by one workman.

Fig. 20.



MOULD CANDLES.—Moulding is a simpler and more expeditious method of making candles than dipping. Pewter moulds of the shape of the annexed figures are usually employed.

They are arranged in a frame made of four solid pieces of hardwood; the top is sometimes an iron plate, in any case it is perforated with holes corresponding to the size of the moulds, and surrounded by a ledge to prevent any loss of material from accidental overflow. The wicks are inserted by

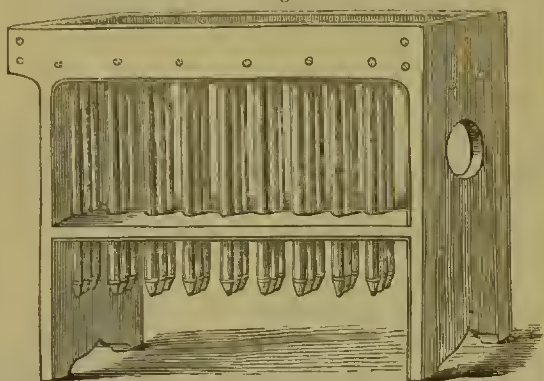
Fig. 21.

hand. After they have been properly adjusted, the tallow or other material (tallow is now scarcely ever used), is poured into each mould singly from a can (Fig. 21), or it may be poured upon the board, and then the whole of the moulds are filled at the same time. In the latter instance, the rim

around the top is provided with a movable flange to facilitate removal of surplus fat, and the moulds are placed closer together (Fig. 22). The frame is then either left at rest, or removed to a cool place till the melted fat solidifies, after which the candles are drawn out.

Figs. 23 and 24 show a common form of mould.

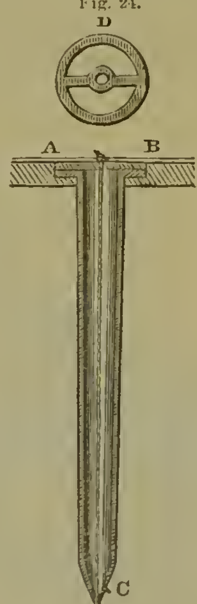
Fig 22.



The pewter of which it is made is generally an alloy of 2 parts of lead with 1 of tin. The body of the mould is proportioned to the size of the candle, and is slightly conical. Its lower end, c, is shaped so as to form the top of the candle, and is perforated in the centre, in order that the wick may pass through; the upper part or base

Fig. 23.

Fig. 24.



has a narrow flange, A B, which supports it upon the top part of the frame. The disc, D, is for the purpose of insuring that the wick is in the centre of the mould. The mould itself is dropped into a hole cut for it in the top of the frame. C is a spigot or plug to fasten the wick before it is drawn tight.

Some candle-makers support the wicks by a series of horizontal wires passed along through the loops of the wicks.

The manner of wicking the moulds is as follows:—A strong wire needle, bent into a catch or hook at one end, and turned into a ring at the other, for facility in handling it, is employed for this purpose. The workman lays the frame horizontally on a table, and taking a number of the prepared wicks in his left hand, he inserts, with the right, the small hooked end of the wire at the lower end of each mould, and as soon as it appears at the mouth lays hold with it of the looped end of the wick, and then withdrawing the wire carries the wick through. The wick, at the mouth of the cylinder, is secured by passing a wire through the loops over each range of moulds. When the whole batch is in this way completed, the frame is restored to its original position, the wicks being first stretched tightly, and fastened by means of a small spigot, or wooden plug, introduced at the lower part.

The moulds used for the manufacture of tallow candles were formerly made of iron and brass. The first substance is now rarely employed; the next is too readily acted upon by the acidity which is liable to prevail in the tallow, and which would destroy the moulds made of it. Pewter is now always used for tallow; but for stearine candle-moulds, instead of pewter, pure tin or a mixture of tin and antimony is used, partly on account of the smutty colour communicated to the candles by pewter moulds, and partly because of the difficulty experienced in drawing them out. In choosing moulds preference should be given to those which are hard and well burnished interiorly. Care also should be taken that the burnishing has been effected by a vertical motion, instead of a rotatory one, as this obviates many inequalities in the mould which would be transferred to the candles. It is also to be observed that, when the moulds are thin, the liquid fat solidifies much quicker than when a large mass of metal surrounds it.

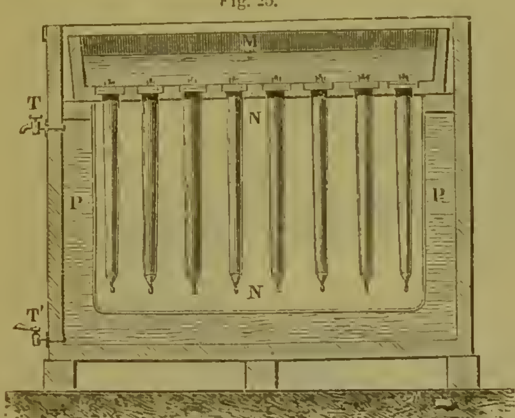
The moulds are filled by running tallow into them, or into the trough in which they are set, from a cistern of melted material, which is kept full by constant supplies from an adjacent vat. When the workman sees that the moulds are half-full he looks to see that all the wicks are tight; he then fills them up. The workman discovers when the candles have set sufficiently to allow of their removal, by a peculiar snapping noise emitted by them when he presses his thumb against the bottom of the moulds. He then withdraws the small wires or spigots which keep the wicks tight, and scrapes off the loose fat from the tops of the moulds with a wooden spade. He next introduces a bodkin into the loop of the wick, and draws each candle out of the mould.

Stearine Candles.—The wicks for stearic acid candles, as before remarked, require special preparation. Pure cotton would absorb too much fat, and burn too quickly; also to keep the proportion of wick to melted matter constant, it is necessary to adopt some contrivance for turning the top of the wick outside the flame, so that coming in contact

with the air outside the blue envelope of the flame (its very hottest part), it may be reduced completely to ash. This is managed by so plaiting the wick that a twist is given to it, which, as it becomes unplaited in burning, causes it to turn outwards. The substances used to prevent too rapid absorption are now made to assist in regulating the length of the wick. The wick is composed of three threads; one thread being shorter, and thus having a greater strain upon it than the others, gives a curvature to the whole plait as soon as the melting of the candle allows it to have free play.

Payen recommends a solution of from $\frac{3}{4}$ to $1\frac{1}{4}$ ounces of boracic acid in a gallon of water, to which a few drops of sulphuric acid has been added. In Austria solution of phosphate of ammonia is used as a pickle. Addition of a little alcohol will insure perfect wetting of the wicks. Dr. Bolley recommends a solution of sal-ammoniac at 2° to 3° B. The wicks, after being soaked in one of the above solutions for three or four hours, are wrung out (a cen-

Fig. 25.



trifugal machine is usually employed), and then dried in a steam-heated iron-jacketed box.

In making stearine candles great care must be taken to avoid crystallization of the stearic acid. 2 to 6 per cent. of white wax, or what is still better, 10 to 20 per cent. of paraffin, is added to the melted stearic acid, and the whole thoroughly mixed by constant stirring. When the mixture of fats has become so cold as to look milky, it is ready for candle making.

The moulds must previously be heated to prevent too sudden cooling of the stearine. Fig. 25 is the hand moulding box used in French candle works; N N is a tin or sheet-iron box in which the moulds are placed. This box is surrounded by a jacket, P P, which is heated to the temperature of 212° Fahr. (100° C.) by a current of steam. The tap, T, is to allow the air to escape on first turning on the steam, the lower tap, T', to let out the water produced by condensation. The vessel, M, acts as a funnel to the moulds. A sufficient amount of stearine is poured in to cover the tops of the moulds. As soon as the moulds are heated to 113° Fahr. (45° C.), the stearine is poured in, and the box, M, N N, is then removed from the steam jacket. When the moulds are quite cold the candles are extracted from them by lifting the surplus stearine which has been poured into M, and to which they are attached.

Moulding by hand is now only in use in small factories. Candle machines, for the purpose of saving time and labour in what by hand is a very tedious operation, are very numerous. The machine now almost universally used is an American invention, many improvements upon which have been patented in this country.

The candle-moulding machines, as made by E. Cowles, are shown in Candle, Plate I., Figs. 1 and 2 (the letters denote the same parts). A A is the iron frame of the machine, with standards, L L, supporting a water jacket, M, through which the candle moulds run. The top of the jacket is somewhat sunk, so as to form a shallow tray (Fig. 2). This is perforated at regular intervals to receive the moulds, which are simple pewter tubes open at both ends. The bottom of each mould is formed by a close-fitting inverted cone, with a hole in its centre for the wick to pass through. These cones, technically called "tips," give shape to the top of the candles: they are sometimes embossed with the maker's name. Each tip is fixed on the top of a hollow rod, which has its lower end fastened to the board, N N. These rods are seen at D. The board, N N, with the attached rods, is raised by the rack-work, O, when its corresponding cog-wheel is turned by the handle, F. The bottom of the machine contains bobbins of wick, E, which revolve on stout iron pins. Each mould has its own spool of wick.

At the top of the machine are two racks, B B, furnished with holes, P P, precisely opposite the moulds beneath, to receive the candles. These racks are hinged at the top. Fig. 3 shows one of them open; Fig. 4 one closed. Each candle is pushed up into its respective orifice, and there secured by turning the handle, C, of an eccentric wedge, which runs the whole length of the rack and nips the two halves tightly together.

The moulds are heated and cooled by sending hot and cold water (or steam and cold water) alternately through the jacket, M. The inlet pipe is at the back of the machine, Fig. 1, and through the axle, R, of the tilting machine, Fig. 2. H is the overflow pipe, and G the valve for running off the water.

In working the machine, connection is made with the hot water or steam-pipe, and the cold water pipe and the outlet pipe seen to be clear of obstructions. The piston-rods, D (Fig. 1), are then raised by turning the crank handle, F, until the "tips" are level with the butt ends of the moulds in the tray. (During this time the racks, B, are not on the machine.) A cotton hook, or a doubled piece of thin wire, is next passed through the "tips" and hollow rods to which they are fixed, until it appears below the board, N. The wick on one of the bobbins, E, is then passed through the bend of the wire, drawn up through the candle mould, and secured in any convenient way. This operation is repeated till all the moulds are "cottoned;" upon which the board with

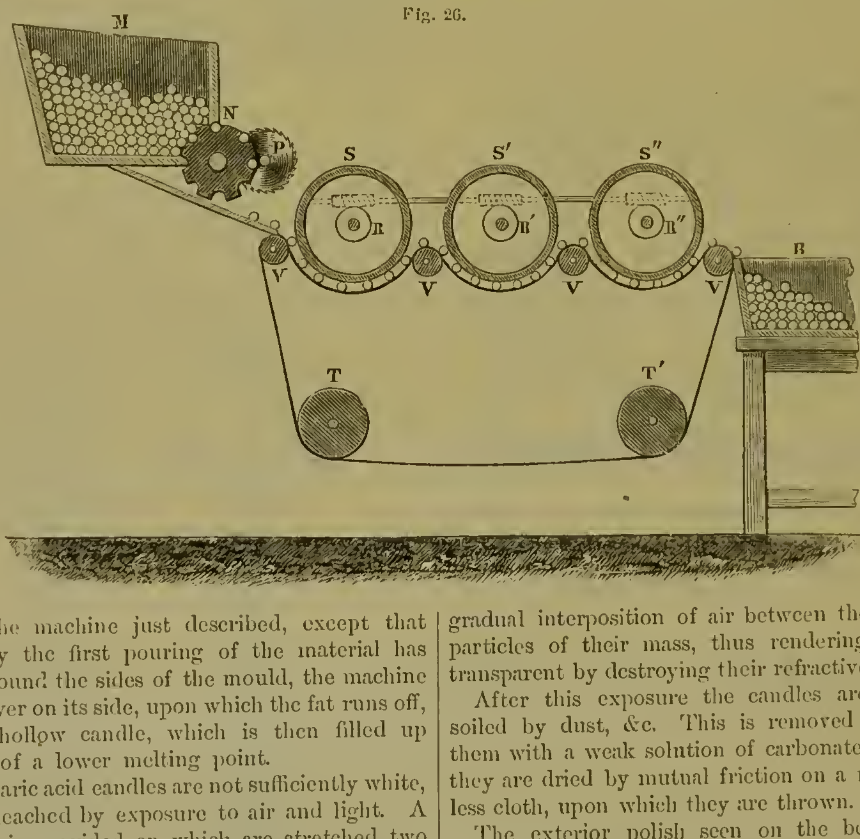
the attached "pistons" is lowered by reversing the crank, F. The moulds are next brought to the desired temperature by hot water or steam, and the melted stearine or paraffin poured into the tray. As soon as the moulds are full, the hot water is run off from the jacket and cold turned on; as soon as the candles are set they are ready for removal. To effect this, the superflous fat is shaved off from their butts with a tin scoop or wooden spade, and the racks, B, B (open), placed in their proper places over the machine, and the handle, F, turned, so as to again raise the pistons on N, N. The candles are thus ejected into the open clamps, which are then closed by turning the handle, C. In Fig. 2 the piston-rods are represented as having just cleared the moulds of candles.

The pistons are now lowered; the "tips" again form the bottom of the candle moulds, in the exact centre of which the wicks, which have been dragged through the perforated tips and rods, are held by the candles, I. Melted material is again poured into the candle moulds, and when nearly set, the wicks at the butt ends of the candles are cut, and the racks, B B, removed, emptied, restored to their places, and the operation conducted as before.

The action of the machine can be seen by a glance at Figs. 5 and 6. The wick is stretched between the bobbins, E E, and the candles, B B; in Fig. 5 the hollow rod, D, with its conical tip, is in the act of ejecting the candle and unwinding the bobbin to supply a wick for the next filling; in Fig. 6 it has returned to its place, leaving the candle in the rack, and the wick stretched between the bobbin, E, and the candle, B. The workman should see that the cotton under the piston plate is slightly strained.

Fig. 2 represents a machine for making candles with an inner core of softer material than the exterior. It differs from Fig. 1 in being movable on the axis, R, through which also the hot and cold water have ingress and egress. It is worked pre-

Fig. 26.



cisely as the machine just described, except that immediately the first pouring of the material has hardened round the sides of the mould, the machine is turned over on its side, upon which the fat runs off, leaving a hollow candle, which is then filled up with a fat of a lower melting point.

If the stearic acid candles are not sufficiently white, they are bleached by exposure to air and light. A framework is provided on which are stretched two lead-wire nets, the one about the height of half a candle above the other. The meshes of the upper net are wide enough to admit of a candle being passed through it, while the meshes of the lower one are narrower. The candles are placed one by one in these meshes vertically, the bases resting on the lower meshes, whilst the conical tips point upwards. In this position they are left for a week or a fortnight, according to the season of the year. The candles are thus to a certain extent bleached, and are also made to appear whiter than they really are by the gradual interposition of air between the crystalline particles of their mass, thus rendering them less transparent by destroying their refractive continuity.

After this exposure the candles are somewhat soiled by dust, &c. This is removed by washing them with a weak solution of carbonate of sodium: they are dried by mutual friction on a moving endless cloth, upon which they are thrown.

The exterior polish seen on the best kinds of stearine candles is given by special machinery. The candle polisher invented by M. Binet is very efficient. Fig. 26 represents it in section. The candles are piled horizontally in the box M. The wheel, N, brings them one by one against the circular saw, P, which pares off the excess of stearine from their bases. They then fall upon an endless woollen cloth, which is distended by the small wheels, V V V V, and the larger ones T T, and passes beneath the three drums, S S′ S″. During the circulation of the endless cloth the three large drums, S S′ S″, which are covered with felt or

some similar material, are likewise moved in the same direction by the three pinions of the toothed wheels, R R′ R″. By the time the candles arrive at the receiving-box, B, they are beautifully polished by the friction they have been subjected to between the two cloths.

PARAFFIN CANDLES.—(The manufacture of Paraffin will be fully described under that title in vol. ii.). FREDERICK FIELD, F.R.S., states that the credit of first manufacturing solid paraffin on anything like an extensive scale is due to Messrs. WILLIAM BROWN & Co., of Glasgow. A very eminent London firm, addressing the secretary of juries of the 1862 International Exhibition, says:—We have been using paraffin in the manufacture of candles since March, 1855. It was made by Messrs. WILLIAM BROWN & Co., of Glasgow, who were, to the best of our belief, the first makers of it in this country, and by whom we were regularly supplied; but from the smallness of the quantity produced (only 3 to 4 cwts. weekly), and its imperfection, especially in hardness, we abstained from offering candles made entirely from it, and merely employed it as an ingredient with other materials in the manufacture of the better class of candles. So far back as 1851 we had assisted in the attempt to obtain paraffin from the bogs of Ireland. It was not until November, 1856, that we received supplies; and from this source, and a quantity of Rangoon paraffin, we, in March, 1857, manufactured and put into the market for the first time paraffin candles of English make. The price at which they were introduced was 2*s.* 4*d.* per lb.

The manufacture of paraffin has since largely increased. The following figures, according to Mr. KENNEDY, express the present annual production in Scotland:—

Shale used in Scotland,	800,000 tons.
Crude oil produced,	25,000,000 galls.
Paraffin,	5,800 tons.
Lubricating oil,	9,800 "
Sulphate of ammonia,	2,350 "

To carry out this manufacture about 500,000 tons of fuel were required.

Paraffin before being made into candles requires purification and bleaching. The following process, "HODGE'S," is carried out on a large scale at PRICE'S CANDLE Co. The crude paraffin having been first separated from rough impurities, is cast into cakes and allowed to cool slowly, so as to form into well-developed crystals. The casks are then placed on a bed of absorbent or porous material, and are while thus placed exposed to a temperature sufficiently high to render fluid the more easily melted matters with which the crystallized paraffin is mixed, but insufficient to melt the paraffin. The melted portions then flow out from between the crystals of paraffin, and into the absorbent or porous materials on which the cake rests. The process may be repeated until the separation of the solid from the liquid hydrocarbons has been effected as completely as is desired.

The partially purified paraffin is by no means colourless, and still possesses considerable smell. Its further purification may be effected as follows, though many processes have been devised. After being melted by steam, it is poured into a tank and agitated by means of air, with from 5 to 10 per cent. of strong sulphuric acid; the sulphurous acid evolved, resulting from decomposition, is conveyed away by a suitable apparatus. The agitation is carried on for some hours, the time depending on the quality of the paraffin. After allowing the whole to rest for some time the paraffin is drawn off, and digested with animal charcoal for some hours; the latter is allowed to subside, and the liquid, if not quite bright, is passed through a filter kept warm by a steam-jacket.

Lately, other bleaching agents have been used. FORDRED, LAMBE, & STERRY, use fuller's earth as a decoloriser of paraffin, in lieu of animal charcoal, whatever the previous process of purification may have been. About 12 per cent. of powdered fuller's earth is added to the melted paraffin, at a temperature of about 230° Fahr., and well agitated, and after subsidence the clear paraffin is run off. The inventors also state that in all their processes, they can replace the fuller's earth in great part or wholly by marl clay, or other readily attainable natural substance of like character. The fuller's earth or analogous substances may be re-used, and the paraffin remaining adhered may finally be recovered from it by washing with agitation or by other suitable means. This discovery of Messrs. FORDRED, LAMBE, & STERRY, has proved of great value, and has done much to bring solid paraffin into domestic use.

ARTHUR SMITH and FRED. FIELD have patented a process in extension of the above. Fuller's earth and many other natural silicates are undecomposable even by strong acids, although certain silicates of lime or magnesia in all these bodies are decomposed when the acids are concentrated, forming a gelatinous residue of silica, and solutions of the bases. It occurred to the patentees that, by forming artificial silicates and employing them instead of the natural silicates, the paraffin or other hydrocarbons might be separated by the addition of very weak acidulated matter. They experimented with the silicates of calcium, magnesium, manganese, iron, and some others, and although all answered admirably, they came to the conclusion that the magnesium salt was the best, a less amount being required to insure the full bleaching action required. At the first glance, any of these substances, even the lime salt, seems too costly to admit of practical application, but this is not the case.

The magnesium silicate is formed by precipitation of magnesium sulphate by sodium silicate. The precipitate is washed thoroughly by decantation and dried by steam. F. FIELD states that the success of this process depends upon the purity of the salt, and the manner in which it is dried. If the gelatinous mass of magnesium silicate were simply desiccated without previous washing, and the soluble saline body (in this case sulphate of sodium) retained, the porous structure, or whatever it may be, of the silicate, would be, so to speak, stopped up, and all bleaching action impeded. And if the washed product were heated

to redness, its decolorizing power would also be destroyed. It must be dried at 212° Fahr. and no higher. Fuller's earth, which is simply ground, contains naturally a large quantity of water, but if heated to redness it is of no avail in paraffin refining. And yet a more singular fact is this, that although we must have a hydrated compound, no bleaching action takes place until the water is separated. Melted paraffin may be agitated either with fuller's earth or artificial silicate for any length of time, without any perceptible action, at a temperature slightly higher than its melting point. The colour disappears when the water is driven off, as if it took its place.

The value of paraffin for candle making depends much on its melting point. FRED. FIELD does not think the difference in the melting point of the different samples of paraffin is as yet understood. He has had samples of paraffin, the melting points of which varied from 130° to 135° Fahr., being as hard as it was possible to make it, and others with melting points as low as 90°, which were yet exactly of the same chemical composition. It is, however, certain that a paraffin of low melting point has always a lower specific gravity than one with a high melting point. Thus there would be about 10 per cent. difference in specific gravity between two samples whose melting points were respectively 90° and 140° Fahr. It is also very remarkable, that if stearic acid which melted at 130° Fahr. were mixed with paraffin which melted at 130° Fahr., the product would be a fusible mass melting at 114°; and if a paraffin with a lower melting point, say 90° Fahr., were mixed with stearic acid, a liquid would be produced remaining liquid at the ordinary temperature of a room. This seems analogous to the fusible alloy made of lead and bismuth, which melts at a point much below that of either of the metals employed.

Candles are made from paraffin mixed with 5 to 15 per cent. of stearin. To prevent crystallization the moulds must be heated to 190° Fahr. (87°·7 C.) before filling, and must be cooled very gradually. Paraffin candle-making machines are fitted with hot and cold water apparatus to insure regularity in working.

Paraffin will not dissolve aniline colours. The tinting material of coloured candles is therefore dissolved in the stearic acid which is used to dilute the paraffin. The colour then remains mechanically suspended. If a tinted candle is melted, and the liquid paraffin passed through bibulous paper, the filtrate is white and the dye remains on the filter.

The insolubility of certain colouring matters, especially those from aniline, may be employed successfully in determining the freedom of paraffin from stearic or other fatty acids. Pure paraffin may be subjected to a temperature of 212° Fahr. with rosaniline for some time, and yet will not take up any of the colouring matter. If, however, it contains only 2 per cent. of stearic acid a pink colour is developed; and if there is as much as 5 per cent. the whole mass becomes crimson.

WAX.—Various organic compounds, of animal and vegetable origin, but differing in composition and physical properties, are designated by the term wax.

Bees' wax (*Cera*) is the principal wax used for candle making.

For a considerable period it was an undecided point among chemists and physiologists, whether the insects which afford wax collected it in its ordinary state from flowers as a part of their food, or whether they produced it by the action of their digestive or other organs. The experiments of HUNTER and HUBER, however, prove that the insect does produce wax; and that it is the work of a certain organ which forms a part of the small cysts or sacs, situated on the sides of the median line of the abdomen of the bee, which may be observed by raising the lower segments of this part of the insect's body, having small spangles of wax arranged in pairs upon each of them. All bees, except the males and queen, in which they are never observed, are provided with eight of these sacs or tunics. Moreover, bees which are fed on sugar elaborate large quantities of wax.

In China wax is produced by a species of *Coccus*. The insect punctures the branches of certain trees and the wax exudes, enveloping them in a soft white coating, which is removed by dipping in hot water. This wax is called "Pela," "vegetable insect wax," and "vegetable spermaceti." According to BRODIE it consists of cerotate of ceryl. In its physical appearance it closely resembles spermaceti. It is snow-white, crystalline, brittle, and fuses at 179°·6 Fahr. (82° C.). By dry distillation it yields cerotic acid and cerotin.

Japanese wax is termed "tree wax," and also, though improperly, American wax. It is not a true wax, being decomposed by treatment with potassium hydrate into palmitic acid and glycerin. It is yellowish white in colour, and about the consistence of bleached bees' wax. It is obtained from the root of the *Rhus succedanea*.

Japanese wax is met with in commerce in round cakes. It fuses at 107°·6 Fahr. (42° C.).

Carnauba wax is described as the outer coating of the leaves of a kind of palm tree, *Kopernicia cerifera*. It is imported from Rio Janeiro, and on account of its high fusion point, 182°·3 Fahr. (83°·5 C.), is used in candle making to improve fats of low fusion point.

Palm wax is obtained from the bark of the *Ceroxylon andicola*, a tree met with on the Cordilleras. The outer bark is scraped from the tree and boiled in water, and the molten wax collected from the surface of the water when cool. It fuses at 181°·4 to 186°·8 Fahr. (81° to 86° C.), and much resembles Carnauba wax.

The berries of the *Myrica cerifera* contain much wax. The fruit of the plant is boiled with water, when the wax separates and rises to the surface. Myrica wax is imported from the southern states, U. S.

A variety known as Ocuba wax is imported from Para, Brazil; it fuses at 96°·8 to 140° Fahr. (36° to 48° C.).

Wax is produced in moderately large quantities in England. The quality of English wax is considered

to be far superior to that of other countries; the quantity is, however, too small for all requirements, and therefore a great deal is imported from Gambia, Mogadore, Ceylon, Singapore, North America, and Brazil. The Gambia wax is difficult to bleach, and is apt to turn brown in a short time. The wax which is sometimes imported from Brazil, and is produced by a kind of black bee which hives under ground, is soft and exceedingly tenacious, and the usual bleaching process seems to have no effect upon it. It is of a dark mahogany colour. By far the largest quantity of wax imported comes from Corsica.

As obtained from the honeycomb of the bee, and from its other sources in the natural state, wax has various shades of colour; that procured by pressing out the liquid contents of the honeycomb, and washing and melting the residue, is yellowish.

Wax is purified from the extraneous matters which generally accompany it, by melting it in hot water or by steam, either in a copper, tin, or wooden vessel, and drawing off the supernatant oily-looking fluid into an oblong vessel, the bottom of which is perforated, for the purpose of distributing the liquid material over horizontal wooden cylinders, which are kept revolving half immersed in cold water. The fluid wax is by these arrangements readily solidified in thin sheets or ribbons, which are afterwards exposed to the bleaching action of air, light, and moisture. On the large scale this bleaching is effected in a way analogous to the old method of bleaching linen. A field with a southern aspect is selected, on which a number of uprights are fixed, and these are used to support strips of canvas or other cloth, fastened horizontally to each of them; upon this cloth the thin shreds of wax are laid, and occasionally watered till the yellow colour disappears. The field should be as sheltered as possible, in order that the light leaves of wax may not be blown off the cloths. The leaves are turned frequently and watered at regular intervals; when the colour seems stationary, and no further improvement appears to be effected, the wax is collected, fused with water, and treated in every respect as before, and again brought to the bleaching ground, where the process is continued till the wax becomes sufficiently white. For greater security against the wind, it is usual to draw a net over the wax spread on the cloths after they are properly watered. In France, where the bleaching of wax forms a considerable industry, bitartrate of potassium is used for the purpose of effecting the purification more quickly. The salt is mixed with the hot water in the first fusion of the wax. The process of bleaching already alluded to then becomes either wholly unnecessary, or is, at least, much shortened.

Neither chlorine gas nor bleaching powder can be used in decolorizing wax; since they render it brittle, and, when used for candles, cause it to smoke and to throw off hydrochloric acid in the act of burning.

In 1859 ARTHUR SMITH patented a process for bleaching wax by the use of bichromate of potassium and dilute sulphuric acid. The bleaching is effected in a few hours, but the cohesion of the wax is somewhat impaired.

INGENHOL gives the following recipe:—

The wax is to be melted, and 2 ozs. of pulverized nitrate of sodium added to every pound weight, and then 1 oz. of strong sulphuric acid, previously diluted with 8 ozs. of water, is gradually poured in, the whole being warm, and stirred while the liquid is being added. The vessel in which the ingredients are brought together should be rather large, as the mixture swells up considerably.

After allowing the wax to cool a little, the vessel is filled with boiling water and set aside for the wax to solidify; when cold it is removed to another vessel and treated with a further charge of hot water, and again cooled; this operation is repeated till all the sulphate of sodium and any trace of nitric acid are removed. If nitric acid remains in the wax it is apt to communicate a brownish colour, which is objectionable.

Pure bees' wax is white, transparent, tasteless, inodorous, and insoluble in water; it fuses at about 145° Fahr. (62°·7 C.), and softens, so as to be kneaded and moulded, at 85° to 90° Fahr. (27°·7 to 32°·2 C.); it has a specific gravity of ·960 to ·966 when solid, but in the melted state, at a temperature of 178° Fahr. (81°·1 C.), the density is 0·834, and at 200° Fahr. (93°·3 C.) it is only ·8247. At 32° Fahr. (0° C.) wax is hard and brittle.

When treated with boiling alcohol repeatedly, a considerable portion of it is taken up, leaving from 10 to 20 per cent. of an insoluble waxy substance called myricin, which is much heavier than ordinary wax, being about the same density as water. The alcoholic solution on cooling deposits the extracted matter; it is called ceroten, and when well purified by repeated crystallizations from alcohol, melts at about 162° Fahr. (72°·2 C.). It appears from BRODIE's investigations that this body is chiefly composed of cerotic acid ($C_{27}H_{54}O_2$). When wax is submitted to distillation scarcely a trace of the cerotic acid remains, although when distilled alone it volatilizes unchanged.

The insoluble substance remaining after the extraction of the ceroten is known as myricin, and consists of palmitate of myricile ($C_{46}H_{92}O_2$) = $C_{16}H_{31}(C_{30}H_{61})O_2$. In addition to these wax contains 4 to 5 per cent. of a body named cerolein, and to which the solidity of wax is attributed.

Wax is not well adapted for making candles by moulding, on account of the tenacity with which it adheres to the mould, and its great contraction on cooling; these difficulties are, however, in a great measure overcome by using glass moulds provided with a casing of gutta-percha. When the candles are to be drawn, the moulds are rapidly dipped into hot water and taken out immediately, by which procedure the glass dilates sufficiently to allow the candles to be removed with facility. The practised hand draws the candles as the moulds are emerging from the hot water. It is well to state that the manager of one of the largest wax candle factories in London has never seen moulded wax candles.

The wicks for wax should be much less than those for any candles yet described. Twisted unbleached Turkey cotton is invariably used, as apparently the fibre resists the temperature of the highly heated wax during combustion better than the usual variety. Plaited wicks are not so well liked as plain, since the plaiting somewhat diminishes the capillary attraction. Their size should be so proportioned that, when the candle is burning, the whole of the melted matter will be absorbed, leaving the cup below almost empty, a full light at the same time being produced.

The basting method is that which is most generally practised; and after sufficient wax has adhered to the wick, the finishing is executed by rolling in the manner about to be described.

Fig. 27.

The ends of the wicks are protected from the wax by a small tin tube or tag, placed thereon for the purpose. Before using the wicks they are heated in a stove, so as to be well dried; they are then taken, and each wick threaded into the metal tag here alluded to, by means of a brass wire catch; an operation, however simple in itself, which should be performed with care, so that the end of the wick may not get charged with the melted material.

This being accomplished, the wicks are conveyed to another workman, whose business it is to pour the melted wax upon them. He performs this operation by suspending the wicks to a hoop placed over a caldron of melted wax, and pouring the liquid on each in succession with a ladle, taking the precaution to cause the wick to revolve on its axis by the motion of the fingers (Fig. 27). When the candles are about one-third made they are allowed to cool for a short time, and then a second basting applied till they are half made, a point easily discerned by the eye, or by the aid of a balance. While still warm, they are rolled between marble slabs to render them of a uniform thickness. The end of the candle is shaped at this stage of the process as follows:—The workman places five or six candles beneath his roller, the slabs being slightly moistened to prevent the wax adhering to them, and by means of a knife cuts off about three quarters of an inch, so as to remove the metal tag on the end of the wick. After this operation is performed, the finished ends of the candles are attached to the ring and suspended as before over the caldron, and the material ladled upon them till they are sufficiently large, when they are rolled as before; and finally, the conical end cut off by a knife to make them of equal length.

When the candle is long, it is usual to bore a hole at the base in its centre to fit upon the spike of the stand upon which it may be placed; and lest this might cause the wax to crack, the end is bound round with a riband stiffened or imbued with melted wax. The ponderous lights burned in churches abroad are made by spreading the wax upon a slab, and placing the wicks horizontally upon it, then folding over the sheet of wax, and finishing the candles by rolling in the usual way. The large candles used in English churches, Westminster Abbey for example, are made by the "basting process," the workmen ascending a ladder to gain command over the wick.

Wax tapers are made by winding the wick upon a drum, and leading it under a guide roller placed in a trough of melted wax; from this it passes through a series of holes on to a second drum, the operation resembling somewhat that of wire-drawing. For white tapers a little tallow is added to render the wax pliable; for coloured, resin and turpentine. The coal-tar colours are now largely used for tinting wax candles and tapers, as well as the following colours:—

Blue—Artificial ultramarine.
Green—A mixture of verdigris and emerald green, or verdigris only.
Yellow—Chromate of potassium—chrome yellow.
Red—Vermilion.
Pink—Madder lake.

Spermaceti Candles.—The candles made from spermaceti are highly prized on account of their beauty and illuminating qualities, and notwithstanding their costliness, are largely exported to India.

The first step is to separate the solid or "head

matter," as it is called, from the sperm oil as it comes from the ships, which is done by filtering it through a long cylinder of bagging lined with linen. The bag is so constructed that, at one end, it is attached to a feed pipe opening into the reservoir, elevated 4 or 6 feet above it, while the other end is bound by a cord. On opening the feed pipe, the cylinder is readily filled, and the pressure then communicated by the stock of matter in the tank forces the oil through in considerable quantities, while the solid spermaceti is retained. Autumn and winter are the seasons for the filtration of the sperm oil, technically "bagging."

The bags are open at both ends, so that the crude or "bagged sperm" is easily removed; it has a dingy brown colour, in consequence of the oleaginous matter which it retains. Considerable portions of this oil are abstracted by the first pressing, which in large factories is applied by the hydraulic, though in lesser works the screw press is used with effect; in either case the sperm is inclosed in suitable quantities in hempen bags, and placed in the frame with plates interposed between them. After receiving the pressure of about 80 to 90 tons, and when no more oil is afforded, it is taken out and melted in the same manner as stearic acid, then drawn off into tinned cases and granulated; finally the blocks, after being thoroughly crystallized, are grated to coarse powder by means of a revolving cylinder studded with knives; this powder, which is collected in a suitable bin beneath the cutter, is filled into cloths with twine wrappers and subjected to the action of a hydraulic press, capable of exerting a force of 600 tons. Some solid matter is forced out with the oil at this stage, and on this account the latter must be passed a second time through the filtering bags.

This completes the process of cold pressing. A large quantity of oil is, however, still retained and cannot be separated by mere pressure. Recourse is therefore had to saponification. To this end the blocks of spermaceti are melted in a large iron vessel, and then boiled for some time with a solution of caustic soda, specific gravity 1·109, in the proportion of $1\frac{1}{2}$ gals. of the lye to 40 of the liquid fat. The oil combines with the alkali, and rises to the surface in the form of soap. Should there be an excess of alkali over what is necessary to combine with the oil on the boiling of the liquid, it would act upon the solid matter and convert it into a soap which would be carried off with the other impurities. To prevent this the solution of the alkali should be weak, or the melted matter ought to be maintained at a low and equalized heat till the oil is taken up, the combination being assisted by stirring the mass. The melted material is now allowed to repose at this gentle heat, during which the soap that has been formed rises to the surface and is carefully skimmed off. To remove all the saponaceous compound in this operation, the whole of the material is raised to about 250° Fahr. (121°·1 C.), and washed with small successive portions of water; meantime the scum as it rises to the surface is carefully removed, until the whole of the melted matter is clear. It is now drawn off into flat tin moulds and left to crystallize; after this is done, the cakes are again ground to powder and submitted to hot pressing in a horizontal steam press in bags of linen, interleaved with horse hair mats and hollow iron plates, in the same way as stearic acid.

Finally, the cakes are once more heated and boiled with a strong alkaline lye, at a temperature approaching 235° Fahr. (112°·7 C.), taking care to remove any extraneous matter that may rise to the surface during the operation. When no more impurities are thrown up, the spermaceti is washed by adding water at intervals in small quantities, the heat being moderated a little at the same time; and as the water falls to the bottom it effects a further purification, leaving the supernatant fluid colourless. It is now cast into blocks and crystallized, and stored as candle stock. Spermaceti is usually mixed with 3 per cent. of wax or paraffin, to destroy its highly crystalline structure; it is "moulded" in the usual way, with plaited wicks that require no snuffing. Occasionally the spermaceti candles are cast without any admixture of wax, the moulds being raised to a higher temperature just as with stearic acid. Some manufacturers, in order to make the spermaceti appear like wax, use gamboge to give the desired yellow tint; such candles are known as transparent wax.

CAOUTCHOUC.—See India Rubber.

CARMINE.—See Cochineal.

CEMENT. — *Ciment*, French; *Cäment*, German; *Cæmentum*, Latin.—In speaking of cements, attention will be given to the more substantial materials used under that name in architecture, as well as to those employed by the jeweller, the marble mason, the manufacturer of china, &c. The term cement is usually applied to such bodies as are capable, by their interposition, of uniting homogeneous and heterogeneous substances, without the aid of mechanical rivets. To do this, however, in such a manner as is sometimes observed in bodies that have been cemented, it is evident that a more intimate union must be effected than that of simple adhesion; in fact, that a chemical combination between the components of the cement and those of the bodies to be united must take place; whereas, in other cases, the virtue of the cement lies in its great adhesiveness, by which it excludes air from the broken surfaces. Many of the preparations, into the composition of which resins, gums, and albuminous bodies enter, act by adhesion, while the mineral cements used in architecture behave differently, in consequence of a chemical combination being formed between them and the body of the substance.

Resinous Cements.—Under this head might be included those varnishes and glues which are employed by the joiner or cabinet-maker, but as these may be more fully referred to subsequently, they will not be further noticed in the present article. Some of these varnishes, when mixed with other substances, form excellent cements: thus, rosin and beeswax melted together, and thickened with brick dust, form a cement used for joining glass and metal work; so

also asphalt mixed with chalk may be used for cementing stones together.

MISCELLANEOUS CEMENTS.—A compound for connecting broken pieces of glass or china-ware is known as *diamond cement*. It is prepared by steeping isinglass in water till it swells, and then dissolving it in proof spirit, to which a little gum-resin, gum ammoniacum, or resin mastic, dissolved in the smallest possible quantity of alcohol, is added. Previous to being applied to the fracture it should be gently heated. It resists moisture to a certain extent. HÄUFLE recommends that 2 parts of shell-lac be dissolved in 1 part of oil of turpentine, and cast into sticks. The same may be employed instead of glue, by dissolving it in spirit, and evaporating to the consistence of a syrup.

KELLER gives the following formula for the preparation of a cement for the same purposes:—2 parts of finely-chopped fish glue are steeped for twenty-four hours in 16 parts of water, then boiled till the liquor is reduced one half; 8 parts of alcohol are added, and the whole strained through linen. While still warm, it is mixed with a solution of 1 part of mastic in 9 of alcohol, and half a part of gum ammoniacum in fine powder; the latter is added gradually, and intimately mixed by maceration. When this cement is used, the parts to which it is applied should be heated, allowed to cool, and then covered with the hot fluid and pressed together. In five or six hours it becomes perfectly hard. This cement is not adapted for very porous substances; for these a concentrated solution of shell-lac in spirit of wine answers best. It should be applied to the thoroughly dried surfaces of the parts to be connected.

A very good cement is formed when shell-lac is dissolved in a concentrated solution of borax. Albumen of egg mixed with quicklime makes a very strong cement, but it does not resist water effectually: it is employed to unite pieces of spar, and marble ornaments to which moisture has little access. Coppersmiths use a similar compound for securing the edges and rivets of boilers, but substitute blood for the white of egg. A very similar cement is prepared by boiling the casein or cheese of skimmed milk in a large quantity of water, and then incorporating the solution with quicklime upon a slab or in a mortar. This strongly unites fractured pieces of stoneware.

VARLEY'S Cement is made of whiting, resin, and bees'-wax, the proportions being 16 parts of the first, well dried by heating it to redness, melted with 16 of black resin and 1 of the wax, the whole being stirred well during the fusion.

An excellent cement, known as *Singer's*, for connecting articles of brass and glass, and adapted for constructing philosophical apparatus, consists of 5 lbs. of resin, 1 of bees'-wax, 1 of red ochre, and 2 table spoonfuls of plaster of Paris, all melted together. URE'S formula for a cheaper compound, adapted for joining voltaic plates into wooden troughs, is 6 lbs. of resin, 1 of red ochre, half a pound of plaster of Paris, and a quarter of linseed oil. The ochre and plaster should be calcined beforehand, and added to the other ingredients while in fusion. A cement nearly colourless is obtained from white wax, resin, and a little Canada balsam. Jewellers sometimes use resin mastic by itself to attach, by heat, cameos of white enamel or coloured glass to a real stone, as a ground to produce the appearance of an onyx. Mastic is likewise used to connect false backs or doublets to stones, to alter their hue. These cements require to be softened by heat before they are applied.

A cement, said to be used by Turkish jewellers, is prepared as follows:—Isinglass is dissolved in brandy or rum, so as to form a strong glue; two small pieces of gum albanum, or gum ammoniacum, are added to every 2 ozs. of this liquid, and triturated until dissolved; and a solution of two or three pieces of mastic, the size of peas, in the smallest possible quantity of alcohol, is added. The cement is kept in a closely stoppered phial: when required for use it is liquefied by placing the phial in hot water.

A concrete, which becomes as hard as stone when set, is made from 20 parts of river sand, 2 parts of litharge, and 1 of quicklime, well ground with linseed oil into a paste. It is very applicable for repairing broken stones, such as steps of stairs and the like. A similar composition, in which porcelain clay replaces the sand, is made for coating brick walls, terraces, &c., and bears the name of mastic. Ordinary asphalt is a cement made from bitumen, chalk, silicious matter, and oil, but this has been already treated in a separate article.

Shell-lac and caoutchouc afford a glue of such adhesiveness that masts may be made by splicing the wood together, and joining them with this varnish, no other fastenings being required to give security; and what is remarkable is the fact that, when such masts have been broken, the fracture has never been observed to take place where the splice has been, but where the wood was whole.

This cement, technically known as "Marine Glue," is formed by dissolving, in about four gallons of coal-tar naphtha well rectified, about one pound of caoutchouc, divided into small fragments. The mixture is well stirred from time to time, till the solution becomes perfect. After ten or twelve days, when the liquid has acquired the consistence of cream, two parts by weight of shell-lac are added to one of this liquid. The mixture is put into an iron vessel, having a discharge-pipe at the bottom, and heat applied. During this operation the whole is kept stirred, and the liquid flowing out of the discharge-pipe in a warm state is spread out upon slabs, and preserved in the form of plates.

When use is to be made of this glue, it is heated in an iron vessel to the temperature of 248° Fahr., and applied hot with a brush to the surfaces to be joined, taking care to spread it in a uniform layer. The pieces of wood are then brought together, and firmly pressed. If the glue should get hardened before the connection be made, it should again be softened by bringing it to a temperature of 150° Fahr. by passing heated rollers over it, and then the joining quickly made. When the surfaces of contact are well dressed, a thin coating of glue on each

is sufficient; but if there be any irregularities in the wood, the glue should be made sufficiently thick to fill these up. Not only may the glue be used for joining shreds of beams or posts, but also for repairing split pieces. The cracks, or crevices, are filled with the glue while at a heat of 248° Fahr.

A very good composition for connecting iron pipes is made from iron filings and chloride of ammonium, ground together, and moistened with as much water as will give the mixture a pasty consistence. It was formerly customary to incorporate sulphur as an ingredient, but it did not increase cohesion; this effect being produced by the oxidation of the iron, which causes it to expand and solidify. The best proportions are 99 of filings and 1 of the sal-ammoniac. Another preparation of a similar nature is formed by mixing 4 parts of iron filings, 2 of potter's clay, and 1 of pounded potsherds, the whole made into a paste with a concentrated solution of common salt; on drying, it becomes very hard.

Building Cements.—Having thus briefly enumerated the principal cementing materials employed for miscellaneous purposes, attention will now be directed to that more important part of the subject which relates to architecture. In this department, the substances which are commonly known by the term cement, whether hydraulic or otherwise, deserve particular notice, as they contribute to the solidity and durability of the building in a remarkable manner. And being so important, it would be well if architects of the present age devoted more of their studies to the consideration of this subject.

How well do the enduring architectural remains of Egypt, Greece, and Rome, as also many of the edifices of the early and middle ages of our era, testify to the quality of the binding medium employed, having withstood the assaults of time, whilst numerous others of later date have mouldered away, in consequence of this material being imperfect!

It has been already stated that the action of hardening, as manifested by some bodies, is due to a chemical as well as a mechanical agency; such is especially the case with mortars, and hence it will be necessary to dwell somewhat in detail upon this subject, commencing with ordinary or common mortar. But, as introductory to this, it may be proper in the first place to say a few words upon the principal component in cement—the lime, and to give a short description of the manner in which it is prepared.

Lime.—*Calcium monoxide* (CaO).—The great source of this compound is the various chalk and limestone (calcium carbonate, $CaCO_3$) deposits found in the geological formations of every country; but besides these, very large beds of calcium salts exist in many other states, and indeed it is met with more or less in all soils, in the ashes of most plants, and also in the bones of animals combined with various acids.

Limestones and other calcareous rocks never exist in a pure state; for, besides the carbonate of lime, which is the principal and nearly the entire ingredient, other substances, such as magnesia, clay, ferruginous and bituminous matters, are contained in them, and from these they obtain their specific names. Only calcareous spar, and a few other minerals, are entirely composed of pure carbonate of lime. Besides the designations *magnesian*, *argillaceous*, &c., limestones are often named from the peculiarity of their *molecular* arrangement. Thus mineralogists give the appellation of *compact*, *pulverulent*, *chalky*, *lamellar*, *saccharoid*, *granular*, *concreted*, *oolitic*, &c., to different limestones, according to their respective species.

Ordinary lime may be prepared from most of these; but the facility of so preparing it is greater in some cases than in others, and the lime itself manifests different characteristics. All that is required is to expel the carbonic acid; and heat is the best agent for effecting this. Kilns of various construction are employed, wherein limestones are burned by the agency of peat, wood, or coal, according as the facilities of the locality offer the one or the other in more or less abundance. The proper form of the kiln is a matter of much interest to lime-burners, as a great economy in fuel may be effected by having it of a certain shape; besides that, when properly constructed it burns much better.

The more common form of kilns exhibits an elliptical section, the upper end being wider than the lower one, wherein is the eye or draft hole. This shape is more advantageous than that of an inverted cone, in which some kilns are occasionally constructed, for the former concentrates the heat more towards the top, and therefore the limestone in this part is acted upon more than it would be if the top or mouth were wider than any other part. Greater facilities are also afforded for drawing off the burned lime, and the kiln itself is less injured, when the form is elliptical or oval.

But where large supplies of lime are required, these comparatively rude forms are laid aside altogether, and a more scientific construction is adopted.

The lime kilns are divided into two classes (1), intermittent kilns, or those whose working is interrupted at each withdrawal of burned lime; and (2), continuous kilns, the operation of which proceeds uninterruptedly.

Fig. 1 shows a vertical section of one of the best of the intermittent kilns, and Fig. 2 a transverse vertical cut, showing the position of the shed placed over it. In the first of these, *a* is the side opening to the back of the fuel chamber, which is about 2 feet square, with iron bars across. On each side of this chamber is an aperture, by which the air is carried to the back, and the entrance of these to the fire is shown at *a* above. The top of the kiln is arched over, the arch springing from *b*. The kiln is fed through the apertures in the arch, and which have cast-iron covers, *c c c*, with lids turning on a pivot appended to them, by means of which the draught is regulated. In Fig. 2 the fuel chamber is shown at *d*, and *e e* are the air-flues between the double doors of the chamber; A is the space where the loading carts stand; *c*, the cast-iron cover of the feeding aperture, and *h*, the cover of the chimney of the kiln shed, B B. This shed over the mouth of the kiln is very beneficial in keeping the materials dry,

and heating them more or less before they are admitted into the shaft. C represents the door by which the limestone is conveyed into B B. The kiln is usually built on the face of a steep bank, and is constructed of fire-brick or fire-stone; the height of the kiln is about 20 to 30 feet, the diameter in the middle is 7 feet, and it is contracted to 3 at the top and bottom.

As an economiser of fuel, the continuous lime-kiln used at RÜDERSDORF is the best. Fig. 3 is a vertical section of this kiln, which is heated by wood and peat. The shaft, C, is like the foregoing, formed of two truncated cones, and is about 45 feet in height. It is 7 feet in diameter at the top and base, and

Fig. 2.

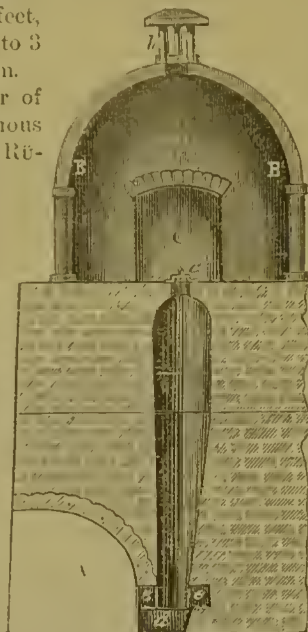


Fig. 1.

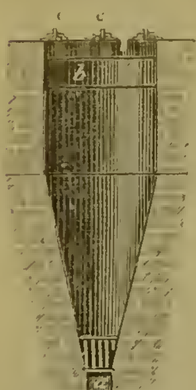


Fig. 3.

10 feet in the widest part, opposite where the fires are situated. In the construction of the shaft, limestones may be used in the walls; but that part to which the heat reaches should be faced with fire-brick, the thickness of which increases from half a brick to a brick and a half in thickness as it approaches the seat of the heat. This lining reaches to the height of 40 feet, and is shown in the figure at *d′*; the wall being represented by *d d*. All these are encased in an exterior wall, *c c*, built of the same material as *d d*, leaving a space of a few inches in diameter, which is filled with ashes and other non-conducting material. This serves to retain the heat, and likewise to afford room for the expansion of the firebricks and stones which takes place when strongly heated. An outer wall, B B, incloses the whole, and the intermediate space is divided into several compartments by means of arches, *p p p*, which serve as drying rooms for wood, fuel, &c. The fires for heating the limestones are three, four, or five, and are seen at *b b*, placed at equal distances from each other. These are arched over, and the arches are lined with firebrick. The grates are composed of two perforated tiles, resting in the middle upon the brickwork, *f*; the perforations in these tiles, by which a current of air, entering by the passage, *h*, is admitted to the fire, are about 1 inch

Fig. 4

wide, and 3 or 4 in length. *g* is closed by an iron door, as also the outlet from *i*, where the cinders collect at first, and then fall into the channel, E, whence they are cleared off through a door, *z*. These doors are left shut until the space, *i*, is filled, and the cinders have sufficiently cooled to be removed conveniently. The draught-holes where the burnt lime is abstracted are seen at *a a*; these are closed with iron doors, which are luted, except at such times as the content is being taken out, in order that the air may not enter at these orifices to cool the kiln. To facilitate the descent of the lime to these apertures, the sole of the kiln is inclined downwards towards them. As the lime is very hot when drawn, the canal, *k k*, is constructed to afford the men protection from the heat; the canal communicates with the chamber P, into which the hot air ascends, a current being instituted in this passage by the fire.

Fig. 4 shows the plan of the preceding, at the lines, Z Z, the section being horizontal with the fires, *b b*, on the one side, and with the draught-holes, *a a*, on the other. When the kiln is set in operation, the

part of the shaft to the level of the fires is filled with limestone, and fires lighted in *a a a*, which are kept burning till the calcination is completed. A fresh quantity of limestones is now let down by buckets upon that already burned, and the supply continued till the shaft is quite full, when a heap, 3 or 4 feet high, is raised over the mouth. The doors at *a a a* being luted on, so as to shut off the draught, the fires are lighted in *b b b*, and kept up constantly. So soon as the upper stones are observed to be well burned, the lime under the level of the fires is drawn out; this causes the top column to fall in, upon which a fresh quantity of limestones is thrown on and piled above the mouth as before. Thus the work progresses without interruption; the lime, however, is drawn only at periods of twelve hours, when about 50 cwts. are abstracted.

The time required for burning lime is affected by many causes, such as the size of the stones, their freshness, and density. It is well known that compact limestones are more difficultly burned than such as are more porous; also, that moisture to some extent facilitates the expulsion of the carbonic acid, even at a lower degree of heat than is required when the limestone is dry. The usual practice of moistening the stones is not so economical as introducing a jet of steam into the kiln; for, in the first case, the heat serves only to evaporate the water before the material can be brought to redness, by which much fuel is wasted; but in the latter, the limestone may be heated to redness, and the steam admitted, when it will be most serviceable. Where kilns like the one above described are being constantly worked, there is a great saving of fuel effected by them; but it is evident that they are adapted only for such places as require a very large quantity of lime, and where, consequently, they can be kept in operation without intermission. Theoretically, the consumption of fuel in causticising or burning lime is only one-tenth of the weight of the limestone; but in ordinary practice, five or six times the quantity which theory shows to be sufficient is used; and where lime is burned for agricultural purposes, and attendance is not very regular, even a much larger amount is consumed.

It is evident, therefore, that those who are engaged in these operations would do well to give the subject their best attention. Much care is required of the lime-burner, especially if the material is of an hydraulic nature, for if he allows the temperature to rise higher than is required to expel the carbonic acid, the lime in consequence loses its property of setting or hardening. This loss of hardening power is probably due to the formation of a layer of silicate of aluminium on the surface of the lime, which prevents water from acting on the lime so as to form a paste.

MORTAR is a mixture of slaked lime and sand in proper proportions. When this mixture is spread in thin layers between stones or bricks, as in building, it gradually hardens and acquires a great degree of tenacity, in a great measure from its gradually reconversion into carbonate of lime, combining at the same time with the substance of the brick or stone, so that the whole becomes one perfect solid. The time required to effect this change is long; for although the mortar becomes sufficiently hard, in a few days or weeks, to enable the wall to bear considerable pressure, still it does not acquire the maximum degree of hardness till after the lapse of many years, and even centuries. From PLINY we learn that the Romans were in the habit of preparing their mortars some time before they were used. One of the causes of the durability of old buildings may be the long period during which the mortar has been exposed to the hardening influence exercised upon it by age; but even this, as is well known, will be ineffectual in bringing the mortar to its greatest power of endurance, unless it be made with the proper admixture of lime and silicious or other matters.

Hydrated lime, alone, is capable of forming a hard cement, but in doing so the mass shrinks very much; it cannot therefore be employed alone as a cement for binding together building materials, inasmuch as the shrinking would cause great unevenness in the construction of walls, &c. As, however, it is found that lime reacts with such bodies as are different from it in composition, especially if they be of a silicious nature, the fact has been taken advantage of, and sand employed from time immemorial to multiply the surface of contact, bring the whole of the hydrate of lime into active combination, as well with this as with the surfaces of the stones or bricks, and prevent the lime from unduly shrinking as it hardens; and thus the union is more thoroughly accomplished. Another requirement for insuring the solidification of the mortar is the presence of just sufficient moisture. If water be not properly supplied, no matter how true the admixture of the other ingredients may be, the mortar will not become firm; if kept in large quantities of this liquid, it will not solidify; and if it be dried as in a stove, it will not form a cement, but remain friable. Exposure to air (*i.e.*, to air containing carbonic acid) is likewise necessary to develop all the properties of the mortar.

Bearing these facts in mind, it is easy for the builder to prepare his mortar or cement so that it may possess all the requisite qualities. The best material is quartz sand, not very fine. When the sand is very minutely divided, then the matter becomes too dense to admit the air which is necessary for its proper solidification; on the contrary, if it be very coarse, the interstices are too large to be filled up with the lime. A good result is obtained when irregularly-shaped stones are employed, by taking a mixture of coarse and fine sand, for it has been observed that the more irregular the foreign body mixed with the lime, provided the surface of contact is sufficiently extensive, the more binding is it. Angular or sharp sand is therefore much to be preferred to smooth, round sand. When the mortar is intended to form a thin coating on the exterior, fine sand is more appropriate.

After ascertaining the materials best suited for the preparation of the mortar, the next step is to pro-

portion them in such a way as to give the best result. This is a work of considerable importance, and any error committed in it cannot be subsequently remedied. As to the quantity of sand which should be taken, much depends upon the quality of the lime; if it be a *fat* lime, that is, if it be devoid of much foreign matters, and fall into a very fine powder in the slaking, it will require about six times the weight of sand; or 3 or 4 cubic feet of sand must be added to 1 of the semifluid milk of lime. Should the lime contain much insoluble matter, or be what is usually known as *poor*, then the volume of sand must be lessened to 2 or 2½ cubic feet. As a general rule, the sand should be mixed with as much of the cream as it will take up without increasing its bulk; and the lime should be so finely divided as to form the thinnest possible stratum between the grains of sand, which it should envelop and bind together. Before applying the mortar the bricks or stones are wetted, in order that they shall not too quickly absorb the water of the mortar.

The cause of the setting of mortar can scarcely be said to be yet determined: it was thought that the hardening was due to mechanical agency exclusively; now, however, it has been found that this is not the case, and that chemical combination contributes materially to render it firm and durable. This chemical action is not wholly confined to the formation of carbonate of lime. The action which takes place during the hardening of mortar appears to be somewhat as follows:—The carbonic acid of the atmosphere acting upon the exposed parts of the mortar forms a coating of calcium carbonate: the amount of this substance formed increases with the age of the mortar; but at no time, so far as we can learn, is the whole of the lime of the mortar converted into carbonate. Mortar from the Great Pyramid was found to contain a considerable proportion of hydrate of lime. That part of the lime is converted into carbonate during the hardening of mortar, may easily be demonstrated by adding a little hydrochloric acid to a small quantity of old mortar, when a brisk effervescence ensues due to the escape of carbonic acid gas. Besides this calcium carbonate there is also formed a small quantity of calcium silicate, by the action of the lime upon the silica of the sand and of the stone or brick; this silicate spreads over the surface of each little grain of sand, and binds the whole mass compactly together.

The formation of the carbonate continues so long as the mortar retains moisture to dissolve the lime and the air has access. Whatever may be the advantages gained from these combinations, they are not sufficient to impart firmness to the material; it is only from the combined influence of the adhesiveness of the mortar to the stone, rendered more intimate by chemical combination, that the full effects are obtained.

Much injury arises to buildings in consequence of impurities being in the materials of the mortar, more especially if they consist of humus, nitrogenous matters, or alkaline chlorides. When these are present, they produce, by their decomposition, deliquescent salts, which attract moisture and occasion damp walls, besides disintegrating the mortar, and consequently destroying its cohesive power. Particular observation should therefore be made, as to whether the sands and water employed in making mortar are free from the substances mentioned. When alkaline chlorides are contained in them they undergo decomposition, giving rise to an alkaline carbonate and chloride of calcium, which is a most deliquescent salt. So ready is this interchange, that it was once proposed as a means for preparing carbonate of soda on a large scale. The humus and nitrogenous matters, when decomposed in the presence of hydrate of lime, produce nitric acid, which, combining with the latter, yields nitrate of calcium—also a deliquescent salt—which is observed in the form of an efflorescence. The amount of sand sometimes added to mortar is so great as to entirely destroy the binding power of the material; very serious accidents have resulted from this cause.

Incrustations, however, appear on the walls, which are not occasioned by any of the forementioned causes, and consequently do not affect the quality of the mortar like those enumerated. They are composed, according to the researches of KUHLMANN, VOGEL, and others, who examined efflorescences of this kind, of sulphate, carbonate, and chloride of sodium, together with carbonate and chloride of potassium; they take their rise from the limestone employed containing these bases. Probably the ash from the fuel used in burning the lime contributes more or less to their formation.

HYDRAULIC MORTAR is made of 1 part of brick powder with 2 parts powdered lime mixed with fresh water. This mortar must be laid in very thick between the bricks, which must be well soaked in water.

HYDRAULIC CEMENTS.—The common material just described is quite unadapted for the erection of docks, dams, lighthouses, and the like, in connection with large trading ports, and coasts dangerous to shipping. For such operations another variety of mortar is used, which has the property of solidifying under water, and hence has been called *hydraulic cement*. On account of the special adaptability of some species of limestones for the formation of this mortar, they are called hydraulic. Such are those calcareous rocks which contain on an average 10 or more per cent. of silica. When these limestones are burned, they comport themselves differently to the ordinary fat lime, inasmuch as they are very slowly slaked, and if the powder thus produced be made into a dough with water, it very soon hardens into a rock-like mass, and remains unaffected by that liquid. The cause of the hardening of hydraulic cements is to be attributed more to chemical combinations than to anything else; it will therefore be necessary to notice more in detail the constitution of those stones which afford a hydraulic lime by calcination, in order to trace their distinguishing quality to its proper source. With this view the following analyses of a few hydraulic limestones are transcribed.

The fresh limestones contain in 100 parts—

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Carbonate of calcium,	89·0	82·5	80·0	79·2	76·5			86·87	82·82
" magnesium,	2·0	4·1	1·0	2·5	3·0	83·40	79·16	3·90	3·76
" iron,	—	—	—	6·0	3·0			—	—
" manganese,	—	—	—	—	1·5	0·90	—	—	—
Silica,			17·0	6·5	11·6	13·97	19·14	5·00	11·76
Alumina,			1·0	3·8	3·6				
Oxide of iron,	9·0	13·4	—	—	—	1·73	1·70	4·23	1·66
Carbon,			—	2·0	—	—	—		
Water,	—	—	1·0	—	—	—	—	—	—
Loss,	—	—	—	—	0·8	—	—	—	—
	100·0	100·0	100·0	100·0	100·0	100·00	100·00	100·00	100·00

The lime obtained by burning the above, contained in 100 parts:—

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Lime,	82·0	79·3	70·0	74·0	68·3	Undetermined.			
Magnesia,	1·5	3·5	1·0	2·0	2·0				
Clay,	16·5	16·7	29·0	17·0	24·0				
Oxide of iron,	—	—	—	7·0	5·7				
Loss,	—	0·5	—	—	—				
	100·0	100·0	100·0	100·0	100·0				

No. 1 is a limestone from the Jura mountains; it is of a light-grey colour, but varies in appearance.

No. 2. Limestone from Nismes; it is yellowish-grey, and is very highly prized as hydraulic lime.

No. 3. This is a marly substance from Senonches; it is disintegrated by water in the ordinary state. Silica remains unaffected when the stone is digested in hydrochloric acid; but it is completely dissolved in caustic potash.

No. 4 is a dense limestone of unknown origin.

No. 5. A limestone from Metz; it is dense, exhibits an earthy fracture, and is of a bluish-grey colour.

No. 6 is a limestone marl from Blankenstein.

No. 7 is from Helbigsdorf, near Freiberg; and

No. 8 and 9 are two samples of excellent hydraulic limestones from the Halkin Mountain, Holywell, Flintshire; they have a compact grain and a dull grey colour. These limestones were employed in the construction of the Birkenhead docks, besides being extensively used in the construction of docks, piers, &c., in other parts of the United Kingdom. The mortar obtained from these stones sets rapidly, and so firmly that the work becomes one solid mass.

	1.	2.	3.	4.	5.	6.
Carbonate of calcium,	67·86	66·99	49·06	76·82	62·47	39·72
" magnesium,	5·62	1·67	29·32	2·81	1·35	28·48
" iron,	3·30	6·95	16·83	3·21	5·85	7·50
Alumina,	—	0·39	—	0·89	0·93	—
Total constituents soluble in hydrochloric acid,	76·78	76·00	95·21	83·73	70·60	75·70
Silica,	15·57	16·89	3·35	11·03	20·93	Undetermined.
Alumina,	4·18	4·32	0·86	2·86		
Oxide of iron,	1·13	1·72	0·43	1·86	7·72	
Lime,	0·15	0·05	0·06	0·12	0·12	
Magnesia,	0·57	0·37	0·01	0·05	0·30	
Total constituents insoluble in hydrochloric acid,	21·60	23·35	4·71	15·92	29·07	
Loss,	1·62	0·65	0·08	0·35	0·33	
	100·00	100·00	100·00	100·00	100·00	

The hydraulic quality of lime depends chiefly upon the amount of insoluble matter, the percentage of silica, alumina, magnesia, or iron, which it contains. This residuary matter is often chiefly composed of silica in the soluble modification. In examining hydraulic limestones, it is necessary to direct attention to the composition of this insoluble residue. In the preceding table, drawn up by HERMANN MEYER, this has been more particularly attended to.

No. 1. This is the limestone from Krienberge, near Rudersdörf, Berlin; it occurs below the sand. It belongs to the upper division of the shellstone, and being in a state of great disintegration, cannot be employed as ordinary mortar.

No. 2 consists of limestone nodules from the Isle of Sheppey; it is yellowish-brown, massive, and firm. These nodules are used in England for the manufacture of *Roman cement*, and occur in

the London clay, which is a member of the tertiary formation.

No. 3. A limestone belonging to the shell limestone formation, which covers the layer of lead ore at Tarnowitz. It is bluish-grey, massive, and nearly crystalline.

No. 4. Cement-stone from Hausbergen. In the manufacture of cement, this stone is mixed in equal proportions with

No. 5, which is a stone from the same locality, and of a poor nature, disintegrated, dark-bluish grey, and slaty.

No. 6. The stone from which Koch's cement is made in Cassel; it is a reddish-yellow, massive, dolomitic marl, from the lower shell limestone.

Kuhlmann has shown that, besides the silica and alumina in hydraulic limestones, other substances previously overlooked in their analyses affect the solidification in a very marked degree. These are the alkalies, which he found in larger proportion in hydraulic than in the ordinary limestone. From this he deduced that the formation of hydraulic limestone was due to the infiltration of a soluble silicate through beds of chalk, by which silica would be retained; and he grounded a means of making cements, and hardening chalk, upon the same principle. His method was to digest the chalk in a solution of an alkaline silicate for a proper period, then to wash with water and dry; the silicic acid unites with the lime, and renders it so hard that it cannot be scratched by the nail.

Hydraulic limestone, if finely ground in the natural state, does not solidify; but after being well burned, and deprived of its carbonic acid, ground or slaked, and then applied as a mortar or cement, it concretes, forming a mass even harder sometimes than the natural rock. The ignition has another effect, by which the silicates, insoluble before the action of the heat, are so modified as to be decomposed by acids, which separate the silicic acid in the form of a jelly. The portion of hydraulic limestone dissolved by acids previous to burning, is that which affords a fat lime when burned and slaked; and the residue is a kind of clay composed of silicates of iron, aluminium, magnesium, lime, and alkalies, with a greater or less proportion of uncombined silicic acid. During the burning, the latter is taken up by the lime rendered caustic by the evolution of carbonic acid, and a silicate is produced which is easily attacked by acids. So perfect is this change, that almost the whole of the metals in well-burned hydraulic limestone may be removed from the silica. The interchange may be explained thus:—At first the heat causticises the stone by expelling the carbonic acid, and the metal acts upon the silicious matters at a high temperature, so that there is a compound silicate of the calcium and other metals produced, which is decomposed by hydrochloric acid.

Again, the caustic lime and the modified silicate react upon each other in the presence of moisture, so as to produce a solid stone-like silicate. In this reaction the water performs an important part; for when lime is mixed with aluminous silicates, these ingredients have little or no action upon each other, unless water be present as a vehicle to bring about an intimate molecular contact. This it does in the mortar during the solidification, by dissolving a portion of the lime, and transferring it to the silicious earth to produce the concrete cement. One great corroboration of this fact is, the necessity which exists of keeping the mortar moistened for some time till it is sufficiently hardened. In this case the change is not owing to the combination of water of hydration, although this may take a part in it; for, were that the case, many silicates which have nearly the same composition would harden under water after being deprived of their combined moisture by ignition; but no such behaviour has been observed. The only way in which the water contributes to harden the cement is, by uniting with the silicate which is formed through this medium, and producing therewith a hydrate. Besides this action resulting in the formation of calcium silicate—probably $Ca_3Si_3O_9$—another action between the lime and the alumina seems to take place, giving rise to an aluminate of calcium, $CaAl_2O_4$. This latter body is slowly acted on by carbonic acid, but so long as the cement contains free lime this disintegrating action is stopped, because as soon as the alumina is set free by the action of the carbonic acid it is presented with a fresh quantity of lime, with which it again enters into chemical union.

The mechanical state of the cement exercises an important influence; if it be coarsely ground, its powers of hardening under water are but slight, but if the cement be ground to fine powder, so many points of contact between the particles are presented, that the action described above takes place quickly, and the hardening of the mass is complete in a short time.

With a limited quantity of water, hydraulic lime at first forms a soft, friable mass; but when afterwards immersed in the liquid, it becomes as hard as stone. The time which various limestones require to harden is very variable, and all of them do not acquire an equal degree of compactness, so much being dependent upon the chemical constitution of the lime, and also upon the treatment which it receives. Some varieties solidify in the course of a few hours, whilst others require a period of thirty days before they acquire any very great degree of hardness or of binding power. The delay in the hardening of such limestones may be owing to the presence of foreign matter, such as gypsum, with which the limestone becomes covered, by the exertion of surface attraction, the water being thus prevented from entering the pores of the mass.

Hydraulic limestones are found in almost every country. Those in which the insoluble matters amount to about 10 or 12 per cent. afford a cement, the hardening qualities of which are not very great, neither are they readily developed; but when the insoluble matters reach to 20 or 25, or from that to 35 per cent., then the substance produced has the qualities required in a very marked degree, and manifests them in a short time, varying from a few hours to three or more days. Although a limestone may be so composed as to be capable of producing a

good mortar under proper treatment, yet, when improperly calcined, many if not all the qualities of the stone may be lost. The burning of the limestone then, which is the chief operation, should be carefully studied, and the temperature regulated with regard to the known composition of the stone; for if the heat applied be too low, the decomposition of the silicious matters will be only imperfectly effected, whilst, if the heat be so great as to cause a semi-vitrification of those constituents, the qualities of the cement will be entirely lost, for those parts will either not slake, or else the whole of the silicic acid will become so entirely saturated with the metals, that no combination will take place when the lime is slaked and made into mortar.

VICAT, who has studied this subject with considerable perseverance, has drawn up a variety of interesting details concerning the effect of heat, &c., upon hydraulic limestones; and from which the annexed particulars are transcribed. In this table, the figures denote the period that elapsed before the cement hardened, which varied according to the amount of carbonic acid contained in it. Thus, when it contained—centesimally—

Carbonic acid.	30	27	26	23	20	10
The mortar hardened in	15 minutes.	12 minutes.	7 minutes.	9 days.	30 days.	9 days.

The several samples of cement upon which these experiments were performed, were obtained from the same variety of limestone.

Hydraulic lime scarcely ever hardens on the first application of water, but only acquires a certain degree of consistence, and then gradually becomes more solid.

As the composition of the cements stands in close relation to the degree of hardness which they assume, it may be well to notice shortly each of the constituents, pointing out at the same time the manner in which they tend to solidify the material.

SILICA, SILICIC OXIDE, *Anhydrous silicic acid* (SiO_2).—Of all the components of cements, except the lime alone, this body is the most important, as the hardening depends upon it. It is met with in two states in rocks and minerals, namely, in the crystalline and the amorphous. Rock-crystal, quartz, the diamond, and many other bodies, contain it in the first condition, whilst opal, flints, and similar compounds contain the amorphous variety. In the crystallized state, silicic acid has very little tendency to act chemically upon bodies in the humid way; but if it be heated to redness with caustic lime or an alkali, then it is brought to the amorphous state, and becomes capable of forming combinations with those bodies. Quartz sand, when mixed with lime, has little value in producing a cement; but if it be first heated with a third of its weight of lime, and then mixed, a considerable difference will be observed in the product. On the contrary, powdered opal, and even precipitated silicic acid, form a tolerably good cement with lime, without heat being applied. It is well known that silicic acid, when freshly precipitated, removes a considerable quantity, if not all of the lime, from its solution in water, a silicate being formed. Such also may be the change which is effected during the hardening of the cements. An excess of silica in the mortar is not, however, desirable, as it does not contribute to its solidity or hardness as much as might at first be supposed; an instance of this fact is, that pitch and pumice-stone, which latter contains from 70 to 80 per cent. of silicic acid, does not make so good a cement as opal and pitch.

ALUMINA.—This earth undoubtedly contributes to the hardening of the cement by combining with part of the calcium set free by the action of the water upon the silicate.

CLAYS.—The clays may be used as substitutes for silicic acid in hydraulic mortars, but being very variable in constitution, it is probable that they operate differently in many samples. To make them as serviceable as possible, they ought to be well burned, as by this treatment their union with lime is greatly facilitated. Many clays, before they will form good cements, must be heated with lime to a very high temperature. This is especially the case with the common ferruginous earths.

MAGNESIA.—When minerals chiefly composed of silicate of magnesium are brought into contact with lime they have no tendency to unite with it, and, therefore, form no cements. If, however, the magnesia is present in excess, as in dolomite, then it contributes to the formation of a powerful mortar. This behaviour of magnesia is owing to the great affinity which exists between it and silica. In the first case, where lime and natural silicate of magnesium are brought into contact, there is no combination, because the silicic acid is united more energetically with the magnesium than it could be with the calcium, and, therefore, no chemical change is produced which might give rise to a silicate of calcium when the powdered mass is mixed with water. But in the case where there is an excess of magnesia, not combined in the natural state with the silicic acid, then, on slaking, the magnesia and silica rapidly unite, and a very firm compound results. Indeed, so powerful is the affinity of silica for magnesia, that the dolomitic limestones always afford a better and more binding compound than if the metal were wholly calcium. Dolomites containing only carbonates of calcium and magnesium, after being burned, will yield a mortar that will set under water; and if silicic acid be present in the proportion of 6 to 10 per cent. or more, a very superior hydraulic mortar results from the formation of a double silicate of magnesium and calcium. Hence, when magnesia is one of the components of the hydraulic lime, and is not combined with the silica in the natural state, the setting of the mortar is afterwards to be attributed in a great measure to this body. The degree of compactness which mortar assumes is, however, to some extent dependent upon the molecular state of the silica, and also upon the amount of the bases combined with it.

ALKALIES.—The alkalies undoubtedly play an important part in giving rise to insoluble silicates during

the solidification of the cements. KUHLMANN and others have shown that such minerals as contain alkaline silicates, part with the whole of the alkali to water, after they have been subjected to heat for some time. This is more especially the case if the minerals contain much lime, as then a silicate of calcium and a carbonate or caustic alkali result. It has been observed that many hydraulic limestones containing alkaline silicates, communicate an alkaline reaction and a saponaceous feeling to the water surrounding the mortar during its setting.

It was on this principle of double decomposition being produced by the alkaline silicate, that KUHLMANN recommended the fusion of a quantity of alkali with the inferior varieties of hydraulic lime, for the purpose of enhancing their value. During his investigations on this subject, he observed that there was a larger amount of alkalies present in limestone than was anticipated, and that they had been overlooked in analyses generally, as iodine and bromine were in many waters. He found that a solution of silicate of soda—soluble glass—when filtered through hydrate of lime, loses a portion of its acid, this being taken up by the lime and producing a silicate. The same effect results if sulphate or carbonate of lime be used instead of the hydrate; and if these compounds be taken in large pieces, and immersed in a solution of soluble glass for some time, their surfaces will become so hard from the silicate of lime formed upon them, that they can be highly polished. The depth to which the silicic acid is absorbed is greater according as the immersion is prolonged, till, ultimately, the chalk becomes as hard as stone, being converted into a silicate of the base. From this deportment of the alkaline silicates, it is evident they serve a very important purpose, by yielding their acid to the lime during the setting of the mortar.

Although it is only the sand, the lime, the magnesia, and a few other substances, which take an active part in the solidification, yet the remaining constituents cannot well be said to be inactive; for though the bodies mentioned manifest their action in a striking manner, still, in the course of time, the latter must have some influence in favouring the binding qualities of the cements.

Having thus explained the nature of hydraulic cements, whereby their properties and adaptation to building purposes may be ascertained according to chemical principles, it may now be desirable to allude cursorily to those physical observations from which a good estimation of the value of cements may be formed.

The limestone being burned, with the precautions already pointed out, it is slaked; and from the manner in which it behaves during this process a good idea of its value as a cement may be obtained. If the material contains few insoluble matters, or, in other words, if it be a rich lime, then on immersing it for a few seconds in water, and depositing it upon a trough or other vessel, it will immediately disintegrate more or less, produce a hissing noise, generate heat, by which considerable volumes of vapour are evolved, and ultimately fall into a very fine powder. When the lime is poor, on treating it with water the phenomena observed in the preceding rich lime are not exhibited for five or six minutes; but after this time they begin to be developed with great force.

With lime of very slight or at least of weak hydraulic properties, the slaking does not manifest itself till about a quarter of an hour after the addition of the water, and even then the heat which is evolved is much less than in either of the varieties already mentioned. When the hydraulic properties are more marked, an hour or so may clapse before the lime shows any symptoms of slaking, and then it disintegrates without making any noise, or giving off a hissing sound like the others. If the substance be a very energetic hydraulic, the period of its slaking is very variable, and the usual phenomena are scarcely perceptible. In many cases it cannot be reduced to powder by the action of water, and the heat produced is scarcely sensible to the touch. Those stones which, previous to being burned, consisted almost wholly of carbonate of lime, swell to double their bulk by the action of water upon them after calcination; the poorer kinds of lime increase but very little, or sometimes scarcely at all. If both these limes were disseminated in a sufficient quantity of water, they would be almost entirely dissolved. The other varieties which have *moderate*, *well-marked*, and *energetic* hydraulic properties, increase in bulk not more than the poorer kind just noticed. They set, or harden, on being immersed in water; but in this respect greatly vary. The moderate hydraulics solidify in fifteen or twenty days, and continue to do so for a year, when they have acquired a consistence similar to that of hard soap. Hydraulic limes of well-marked properties set under water in five or six days, their density increasing during a period of six or twelve months. At the end of this time the tenacity is about equal to that of the softer kind of building stone. Water exerts but little action upon them afterwards. The energetic hydraulic limes harden in three or four days after immersion in water, and in six months they assume the induration of compact limestone, so that they are quite unaffected by the action of a stream of water.

The most important cements in general consumption are those known as *Roman* and *Portland* cements. The other varieties have been almost wholly superseded by these valuable building cements. Portland cement is an artificial mixture of chalk and clay, whilst Roman is prepared by burning a natural cement stone. The cements from plaster of Paris are used by decorators.

ROMAN, or more properly PARKER'S CEMENT, is so called after the similar material which the ancient Romans prepared out of a species of porous rock found in the neighbourhood of Puteoli, near Naples, and known at the present time as *puzzolana*. This substance, which has been analyzed by BERTHIER, whose results are appended, is the product of volcanic eruptions:—

	Centesimally represented.
Silica,	44·5
Alumina,	15·0
Lime,	8·8
Magnesia,	4·7
Oxides of iron and titanium,	12·0
Potash,	1·4
Soda,	4·1
Water,	9·2
Loss,	0·3
	100·0

Another variety of this substance has been discovered by SAUVAGE in the Departement des Ardennes, which does not present any feature to show its volcanic origin. Its composition is—

	Centesimally represented.
Soluble silica—gelatinous,	56·0
Clay,	7·0
Fine quartz sand,	17·0
Fine grey limestone—chlorite,	12·0
Water,	8·0
	100·0

This variety occurs below the chalk, resting upon a fossiliferous deposit of clay; it is very soft, and has a pale, greenish colour.

As the Romans extended their sway westward into Germany, they soon found deposits of material similar to that at Puteoli, and to which the name *tarras* or *trass* has been given. So extensive are the beds of this material near Bonn, that the quarries opened there by the Romans have been worked ever since, and the product transmitted to all parts of the country. It is of volcanic origin like puzzolana, and gives indications of being thrown out by the burning mountains of Eifel. A sample of trass from Brohlthal afforded to ELSNER the annexed numbers:—

	Centesimally represented.	
	Soluble in Acid.	
Silica,	11·50	
Oxide of iron and traces of manganese,	11·77	
Alumina,	17·70	
Lime,	3·16	
Magnesia,	2·15	
Potash,	0·29	
Soda,	2·44	
		49·01
	Insoluble in Acid.	
Silica,	37·44	
Alumina,	1·25	
Oxide of iron,	0·57	
Lime,	2·25	
Magnesia,	0·27	
Potash,	0·08	
Soda,	1·12	
		42·98
Water with traces of ammonia,		7·65
Loss,		0·36
		100·00

Trass and puzzolana are admirably adapted for the manufacture of cements of hydraulic properties; for, as will be seen by the preceding analyses, they contain a large quantity of amorphous silica which combines with the lime, as well as considerable quantities of alumina and iron which also enter into combination; and besides, the large amount of the alkalies present in them contributes materially, as has been already shown, to the setting of the compound in water. Both these varieties are generally ground by stamping mills to a very fine powder, and then exported. It was for a substitute for this material that Mr. PARKER obtained a patent about the year 1796 to produce the *Roman cement*. The substances employed by him were such as still continue to be the basis of this material; they are nodules of an ovoidal or globular form found in the London clay, and known by the term *septaria*. It was thought that these nodules were confined to the few places in which they were then discovered; but as the search for them became more general, they were detected at Harwich, Southend, in the Isles of Wight and Sheppey, and also on the coasts of Kent, Somerset, and Yorkshire, as well as in Flintshire, Calderwood in Scotland, and on the coast of France.

These cements contain about 60 per cent. of calcium or magnesium carbonate, with from 30 to 40 per cent. of clay. They seldom contain alumina or soda, and hence are far inferior to artificial Portland cement. The following table shows the relative quantities of the constituents:—

	Clay.	Calcium Carbonate.
	Per cent.	Per cent.
Parker's cement,	45·0	55·0
Yorkshire,	34·0	62·0
Sheppey,	32·0	66·0
Harwich,	47·0	49·0

Southend cement:—	Per cent.
Ferric oxide,	9·0
Silica,	12·0
Alumina,	3·4
Calcium carbonate,	64·0
Magnesia,	1·5
Calderwood cement:—	
Ferrous oxide,	10·2
Silica,	8·8
Alumina,	3·4
Calcium carbonate,	64 0
Magnesium,	2·6

Cement stone is found in the United States, which contains more alumina and less calcium carbonate than the English variety.

The mode of manufacture is very simple, and is that which was originally proposed by PARKER. The stones are burnt at the highest temperature possible short of vitrification, the aim of the maker being to get a cement of the lowest possible specific gravity. In this respect there is a great difference between Roman and Portland cement, since the latter is best when it possesses the greatest weight. A bushel of good Roman cement should weigh about 75 lbs., a bushel of the best Portland cement 140 lbs.

The kiln used is very similar to the common lime kiln. It is generally from 20 to 25 feet high, from 9 to 12 feet wide at the top, and from 7 to 8 feet wide at the bottom. Its internal capacity is between 70 and 80 tons. The stone is broken into pieces from 2 to 3 inches square, and placed in the kiln in layers alternately with a sufficient amount of coal dust to insure its complete decarbonization when burnt. When once lit, the kiln is worked continuously (sometimes for months); the burnt stone being withdrawn at the bottom, and raw supplied at the top of the kiln. The stones are then crushed by stampers and heavy edge stones to a very fine powder, and after removing any coarse frag-

ments by very careful sifting through sieves of about 1600 meshes to the square inch (No. 40 gauge), the powder is packed in casks. The powder readily absorbs carbonic acid and moisture from the air; it hardens very quickly. Medina cement is of the same nature as Roman, except that the septaria employed are those of Hampshire. Mulgrave or ATKINSON'S cement is prepared in a similar way from the lias and other species of rock.

Roman cement is at its best when freshly burnt, as it deteriorates rapidly by keeping. Portland cement, on the contrary, keeps well even when exposed to the air. Roman cement will not bear a larger admixture of sand than 1 to 1. For foundations, however, a concrete may be used of 5 to 6 parts of gravel to 1 of cement.

PORTLAND CEMENT.—This artificial cement, which has gained a deservedly great reputation, and is decidedly superior to the others in point of tenacity and durability, is made by intimately mixing chalk and clay.

The relative quantities to be used of each material depends on the amount of calcium carbonate in the rough chalk, and of silica and alumina in the clay. If the clay contains no more than 15 per cent. of iron oxides, 20 parts of clay to 80 parts of chalk is about the correct proportion.

The mixing is performed under water, the greatest care being taken to avoid leaving any lumps of clay and chalk in the mud thus formed. The mixture is then run into large pits, and after prolonged settling the supernatant water pumped off. As much as possible of the remaining water is drained off, after which the mud is dried and burned in proper kilns, ground like the cements just described, sifted, and packed for sale. The process, though inexpensive, is a very slow one, and occupies from two to three months.

Cements of various degrees of setting qualities are manufactured in Germany by calcining clays and limestones in the same way as the foregoing, but much of their power is dependent upon the nature of the clay, and the degree of heat at which calcination is performed. They are, however, for the most part, inferior to those made by the wet way, as well in the property of setting under water, as in the tenacity with which they bind bodies together. The process pursued is such as the following. The raw materials, limestone and clay, or mud, are intimately mixed in equal quantities, the mixture is dried in the air, and then burnt in a shaft oven. A layer of coke alternates with a layer of cement stone. At a white heat the mass becomes grey, with here and there a streak of green; at this stage it must be removed from the oven, as, if the heating be continued the mass becomes blue-grey in colour, and is useless as a cement.

Portland cement sets very quickly when mixed with water to the consistence of a pulp; after a month it becomes so firm and hard as to emit a musical sound when struck by a hard body.

The following are analyses of various samples of Portland cement:—

	1	2	3	4	5
Lime,	59·06	62·81	61·64	55·06	57·83
Silica,	24·07	23·22	23·00	22·92	23·81
Alumina,	6·92	5·27	6·17	8·00	9·38
Oxide of iron,	3·41	2·00	2·13	5·46	5·22
Magnesia,	0·82	1·14	—	0·77	1·35
Potash,	0·73	1·27	—	1·13	0·59
Soda,	0·87		—	1·70	0·71
Calcium sulphate,	2·85	1·30	1·53	1·75	1·11
Clay, Sand,	1·17	2·54	1·28	2·27	—

No. 1 and 4 are English Portland cements. No. 2 is a Stettin cement. No. 3 is called Star cement. No. 5 is a cement made at Bonn.

Concrete and *béton* belong to the class of mortars, and are much used in underground works, and in the foundations of large edifices. They also serve as a backing for walls of great thickness. They are prepared by mixing coarse gravel and fragments of stone with lime, which may or may not have been previously worked up into mortar.

For water-works, where it is necessary that the compound should set rapidly, a mixture of hydraulic lime, puzzolana, and sand, may be used in the annexed proportion, recommended by TREUSSART:—

30 parts of strong hydraulic lime measured in bulk before being slaked,
30 do. of trass,
20 do. of gravel,
30 do. of sand, and
40 do. of hard limestone broken.

These materials diminish one-fifth after being worked up. The stones and gravel are added after the sand and lime have been mixed up into a mortar. This cement should be used immediately after it is made. When the puzzolana is used, the proportions taken are:—

32 parts of strong hydraulic lime measured before slaking,
44 do. of puzzolana,
22 do. of sand,
60 do. of broken stone and gravel.

This concrete is exposed for twelve hours before it is used.

For river and sea works a concrete similar to the above, and answering the required purpose very well, is manufactured by mixing a mortar made of three parts of quartz sand, and one of unslaked hydraulic lime, with an equal weight of gravel or broken stones. No water should be added to the mixture during the time the mortar is being incorporated with the stones and gravel.

If the latter have a smooth surface, they are not so well adapted for the preparation of concretes of this description, as when they are angular and pointed. Granite clippings and other fragments are very eligible for this kind of mortar. Much difference exists between the behaviour of concrete and that of béton in water, for the former does not set, and therefore is acted upon by the water, if not protected, whilst the latter is eminently hydraulic.

COIGNET'S CONCRETE.—Sand is mixed with one-fourth its weight of lime and one-twentieth its weight of Portland cement. A very small quantity

of water is then added, and the whole ground in a mortar mill till a pulverulent paste is obtained, which on further grinding becomes a firm plastic mass. The mixture is then ready for the mould, into which it is introduced in thin layers and powerfully rammed until its bulk is reduced one-third. A few days, sometimes a few hours, suffice to convert the whole into a hard stonelike mass. Buildings made with this material are practically homogeneous, since the work of one day unites without visible join with that of the preceding.

Decorator's Cements, such as Keene's, Martin's, Parian, &c., have gypsum or plaster of Paris for their basis instead of a hydraulic lime. The method of preparation is almost the same in all.

Gypsum differs from those substances hitherto considered, as well in its chemical constitution as in its behaviour as a cement. The several mortars and cements already described owe their property to the formation of a silicate during the setting, but in the case of gypsum or plaster of Paris no such combination takes place; indeed, its hardening properties are rather diminished than enhanced by admixtures of caustic lime or silica.

The induration of gypsum is, however, to be attributed to a union of another kind, namely, of water. Gypsum, or sulphate of lime, when exposed to the air for a length of time, will not set when mixed with water in the usual way, because the necessary amount of constitutional water for the formation of the crystallized salt had been absorbed from the atmosphere. If this substance were, however, exposed to a high temperature, sufficient to expel all the moisture with which it united, and the dry powder blended with water, it would readily harden. The gypsum, in this case, unites with about a fourth of its weight of water, by which it is rendered crystalline; but besides this amount it is capable of enveloping or solidifying a much larger quantity. By reason of this behaviour, gypsum forms a solid mass with as much as its own weight of water. With such an amount, however, it never acquires much tenacity, but, upon the evaporation of the excess, the portion of the salt which was dissolved assumes the crystalline form and binds the solid particles more firmly together. This property of gypsum makes it very valuable for many architectural and artistic purposes, but only those connected with cements will here be alluded to. The setting of gypsum depends upon the production of the crystalline hydrate, $CaSO_4.2H_2O$. By examining the wet mass of burned gypsum and water under a microscope, this process of crystallization becomes evident. As ordinary burned gypsum contains about 8 per cent. of water, an addition of only 12 per cent. is necessary for the formation of the solid hydrate. In practice as much as 33 per cent. of water is often added, as it is found that unless the mass be semi-fluid it hardens too quickly. The cement thus produced is porous, and is rapidly acted on by the atmosphere with the production of nitrate of calcium. The addition of such substances as gum, gelatine, glycerine, &c., delays the crystallization, and hence diminishes the rapidity of setting of gypsum; such bodies may therefore be employed for this end, a smaller percentage of water being added.

Sulphate of calcium, when set by water, never acquires the tenacity of stone; it always remains soft, so that it may be easily scratched by the nail. This softness was a great impediment to the execution of several works in plaster, and for a long time a remedy was sought, with only partial success. Various suggestions and prescriptions were offered, most of which were unavailing. Gay-Lussac first observed that the hardest natural gypsum also yields the firmest product after setting in the usual manner.

The proposition of hardening gypsum by means of a solution of alum was first made by Pauware, and carried out with modifications by several persons; and this has proved the best, or one among the best and readiest means by which tenacity may be communicated. The alum solution used contains 20 ozs. of alum to 6 lbs. of water. Other salts in solution are capable of effecting the same change, some by a double decomposition being induced; thus gypsum and bitartrate of potash give tartar and crystallized gypsum; whilst with others the theory of the induration by their means is not so easily demonstrated. The hardening with alum is accounted for by the fact that sulphate of lime is capable of combining with another salt forming a binary compound, in the same way as sulphate of magnesia unites with other sulphates; thus gypsum and potash alum form a double sulphate, having the formula $CaSO_4 + K_2SO_4 + H_2O$. It is of this behaviour of gypsum with solutions of salts that advantage has been taken, and patents secured for manufacturing the cements noted above.

Keene's cement is made by mixing the powdered gypsum with a solution of alum, and then baking the compound at a temperature approaching dull redness, so as to dissipate the whole of the combined water. The mixture is again powdered by stampers, or ground under edge stones. When used the powder is slaked by a solution of alum in 12 or 13 parts of water. Common water might here be employed, but that hardness which is given by the alum liquor could not be attained.

Martin's composition is made in the same way as the one just described, only that carbonate of soda, or carbonate of potash, is employed as well as the alum, and the burning takes place at a higher temperature.

Parian cement is prepared by using a lye of borax containing 1 part of borax and 9 parts of water, instead of the forementioned. These varieties are very useful for floorings, skirtings, &c., and especially where damp and vermin have to be guarded against. These materials, like stucco, may be employed in cementing walls, and their surface can be embellished with various artistic delineations similar to fresco-painting.

Stucco is a compound of powdered gypsum and a solution of glue or strong gelatine, which is employed

to coat walls, and also for ornamenting ceilings, and other works of art. It is capable of receiving a high polish, and also of taking designs in colour. When employed on walls, the coarser kind is first laid on, and an outer coating of a finer preparation of gypsum and glue, or isinglass, afterwards deposited upon it, and when dry, polished with pumice, tripoli, and linen rubbers. The colour is incorporated with the outer coatings of the stucco, by mixing the metallic pigments with it, and then applying it to the wall, after which a very thin coating of gypsum and isinglass, or sometimes of oil, is given; and when the whole is partially dried, the tint is brought out by polishing, as before stated. Generally, the finest is given with oil.

A very good hydraulic mortar is made by slaking lime with water containing about 2 per cent. of gypsum, and adding a little sand to the product. The presence of the gypsum tends to delay the slaking of the lime, and also to harden the substance formed after the slaking. If water containing a little lime in solution be added to burnt gypsum, a very hard compact mass is obtained: this substance is much used as an imitation marble, as by polishing it with pumice stone, colouring it, and again polishing with oil, it may be made to resemble natural marble very closely. Hardened gypsum treated with stearic acid or paraffin and polished, is used as a substitute for meerschaum, which it much resembles.

Mosaics.—The processes of forming patterns and devices by the cementation of several pieces of coloured and other substances, is one exhibiting great art and skill. The ancient Romans excelled in this, as is evidenced by the fragments of pavements and other remains which have been discovered in the various countries they subdued. Rome and Florence still continue pre-eminent in this kind of work; but instead of it being, as of old, exclusively used to decorate walls and floors of buildings, it is now employed by artists for copying the most delicate paintings, the material for this purpose being a kind of very fusible enamel, tinged by metallic oxides. This constitutes the surface of the picture, being supported on a ground of very hard cement. It is said that no less than 1,700,000 pieces of this composition entered into the construction of a portrait of one of the popes, exhibited at the International Exhibition of 1851.

The following processes for preparing mortars and hydraulic cements which are used by the Turks, may be interesting:—

Ordinary mortar is prepared by mixing 2 parts of powdered lime, and 1 of river sand, with the necessary quantity of fresh water.

Hydraulic mortar.—Bricks are triturated till their powder appears of the fineness of common river sand; 1 part of this is afterwards mixed with 2 parts of fine lime, and the necessary quantity of fresh water. When using this mortar, it is laid between the bricks, or courses of bricks, in layers as thick as the latter. To render it very binding, the bricks are allowed to remain in water till they become saturated. When the mortar is used for the internal dressing of arches, aqueducts, large cisterns, or reservoirs, baths, &c., it is made in the following manner:—

250 lbs. of milk of lime, and 220 lbs. of extremely fine plucked tow, are to be mixed together very intimately and regularly. The whole is allowed to stand for eight days, that the lime and tow may form a thorough combination. Before being used, it is well stirred up. It is laid on in the usual way, by means of a small trowel, and afterwards subjected to the dressing, which consists in a prolonged rubbing with the trowel, till the surface is smooth and even. To render the cement unaffected by water and more durable, it is covered with a layer of the following composition:—

250 lbs. of fresh burned lime slaked,
62 lbs. of linseed oil, and about,
2 ozs. of rough cotton.

The lime is mixed with the oil and cotton in successive portions, till the mass has the consistency of dough. It is then moulded into square blocks and preserved for use. Before being applied, it is stirred up with linseed oil to bring it to the thickness of a stiff paste.

CHLORAL AND CHLOROFORM. Chloral (C_2HCl_3O).—This compound was discovered in 1832 by Liebig (*Ann. Chem. Pharm.*, vol. i. p. 189) whilst studying the action of chlorine on dry alcohol, and was subsequently investigated by Dumas (*Ann. Chim. Phys.* [2], vol. lvi. p. 123), and by Staedeler (*Ann. Chem. Pharm.*, vol. lxi. p. 101).

Preparation.—On passing pure and dry chlorine into well cooled absolute alcohol, the gas is absorbed with the greatest avidity at first, but after a time the action becomes less powerful, and the liquid assumes a yellow tint. It must then be gradually heated, ultimately raising the temperature to near the boiling point, whilst a rapid current of chlorine is still passed into the liquid. During the whole of the operation large quantities of hydrochloric acid are given off, and also much ethyl chloride; the latter being produced by the action of the hydrochloric acid on the unaltered alcohol.

After the liquid is saturated with chlorine, which takes about twenty hours for 8 ozs. of alcohol, the thick oily product, if put aside for a few days in a cool place, solidifies to a crystalline mass of impure chloral alcoholate. In order to obtain pure chloral from this, it must be fused and agitated with four or five times its bulk of concentrated sulphuric acid for a few minutes. On allowing the mixture to stand the anhydrous chloral rises to the surface as an oily layer, which must be removed as quickly as possible, for prolonged contact with the acid would convert it into the insoluble metachloral. It is then rectified over lime, which has been slaked and subsequently ignited, in order to remove hydrochloric acid, but care must be taken that none of the lime rises above the surface of the liquid, as it will otherwise decompose the vapour and become red-hot. In this manner the chloral is obtained tolerably pure, but it still contains traces of water and of alcohol, which may be removed by another treatment with sulphuric acid and subsequent rectification over lime.

STAEDELER also obtained chloral by distilling 1 part of starch or grape sugar with 7 of hydrochloric acid, and 3 of peroxide of manganese, adding a little common salt to neutralize the injurious effect of the sulphuric acid produced from the sulphurous anhydride which usually occurs in commercial hydrochloric acid. The aqueous distillate, separated from the oily drops, is saturated with salt and repeatedly redistilled, carefully removing the oil each time. The concentrated aqueous solution of chloral is then saturated with dry chloride of calcium, and distilled in an oil bath at 120° C. Hydrate of chloral passes over as a colourless liquid, which solidifies in the receiver to a crystalline mass.

It might be imagined that the action of chlorine on alcohol was a very simple one, being merely the removal of two atoms of hydrogen and the replacement of three of the remaining atoms by chlorine, forming chloral, thus:—

$$\underset{\text{Alcohol.}}{C_2H_6O} + Cl_2 = \underset{\text{Aldehyde.}}{C_2H_4O} + 2HCl,$$

and that the nascent aldehyde is then transformed into chloral—

$$\underset{\text{Aldehyde.}}{C_2H_4O} + 3Cl_2 = \underset{\text{Chloral.}}{C_2HCl_3O} + 3HCl.$$

From the elaborate researches of WURTZ and VOGT (*Compt. Rend.*, vol. lxxiv. p. 777), however, it would seem to be much more complicated; the first action of the chlorine on the alcohol is indeed, as above represented, to remove two of the hydrogen, forming aldehyde:—

$$\underset{\text{Alcohol.}}{CH_3.CH_2.OH} + Cl_2 = \underset{\text{Aldehyde.}}{CH_3.COH} + 2HCl.$$

The hydrochloric acid then acting on this aldehyde and on the excess of alcohol forms monochlorether:—

$$\underset{\text{Aldehyde.}}{CH_3.CHO} + \underset{\text{Alcohol.}}{C_2H_5.OH} + HCl = \underset{\text{Monochlorether.}}{CH_3.CHCl(OC_2H_5)} + OH_2.$$

The monochlorether is then converted into tetrachlorether by the continued action of the chlorine—

$$\underset{\text{Monochlorether.}}{CH_3.CHCl(OC_2H_5)} + 3Cl_2 = \underset{\text{Tetrachlorether.}}{CCl_3.CHCl(OC_2H_5)} + 3HCl,$$

and this, by the action of water, splits up into alcohol, hydrochloric acid, and chloral, thus:—

$$\underset{\text{Tetrachlorether.}}{CCl_3.CHCl(OC_2H_5)} + OH_2 = \underset{\text{Chloral.}}{CCl_3.CHO} + HCl + \underset{\text{Alcohol.}}{C_2H_5.OH};$$

or, as the final result of the action of chlorine on alcohol is not chloral but chloral alcoholate, the last reaction may take place thus:—

$$\underset{\text{Tetrachlorether.}}{CCl_3.CHCl(OC_2H_5)} + OH_2 = \underset{\text{Chloral Alcoholate.}}{CCl_3.CH(OH)(OC_2H_5)} + HCl.$$

It must be stated, however, that although the action of chlorine on a mixture of aldehyde and concentrated hydrochloric acid appears to produce some chloral hydrate, the principal products are dichloraldehyde and crotonic chloral.

LIEBEN, on the other hand, considers the formation of the chloral alcoholate from alcohol to take place in a different manner. In 1857 he showed that the action of chlorine on alcohol at ordinary temperatures gave rise to mono, di, and tri-chloracetal, and PATERNO, in reinvestigating the subject, found that at 80° C. the higher chlorinated derivative is formed in considerable quantity. This is a solid crystalline substance, which by the action of concentrated sulphuric acid appears to give chloral, although PATERNO and PISATI's experiments are not quite conclusive on that point. An isomeric liquid modification of trichloracetal is formed on heating tetrachlorether with alcohol in the manner shown in the following equation:—

$$\underset{\text{Tetrachlorether.}}{CCl_3.CHCl(OC_2H_5)} + \underset{\text{Alcohol.}}{C_2H_5.OH} = \underset{\text{Trichloracetal.}}{CCl_3.CH(OC_2H_5)_2} + HCl;$$

and this compound, according to WURTZ and VOGT, when heated with water or sulphuric acid, yields alcohol and chloral,

$$\underset{\text{Trichloracetal.}}{CCl_3.CH(OC_2H_5)_2} + OH_2 = \underset{\text{Chloral.}}{CCl_3.CHO} + \underset{\text{Alcohol.}}{2C_2H_5.OH};$$

or chloral alcoholate and ethyl chloride may be simultaneously formed from it by the action of hydrochloric acid, thus:—

$$\underset{\text{Trichloracetal.}}{CCl_3.CH(OC_2H_5)_2} + HCl = \underset{\text{Chloral Alcoholate.}}{CCl_3.CH(OH)(OC_2H_5)} + \underset{\text{Ethyl Chloride.}}{C_2H_5Cl}.$$

It will thus be seen that the difference between the two hypotheses is really as to whether the tetrachlorether which is formed splits up at once in contact with water into alcohol, hydrochloric acid, and chloral, or as to whether it is first converted into the liquid modification of trichloracetal by double decomposition with alcohol, and that the trichloracetal is then decomposed by water, or by hydrochloric acid, with formation of chloral and alcohol, or chloral alcoholate and ethyl chloride. Whatever may be the series of reactions which takes place, it is certain that the final product is chloral alcoholate.

In the action of chlorine on alcohol, hydrochloric acid is produced; and this by a secondary reaction on the excess of alcohol gives rise to large quantities of ethyl chloride, part of which escapes, and part is converted by the chlorine into ethylidene chloride.

Properties.—Anhydrous chloral, C_2HCl_3O or $CCl_3.COH$, is a thin oily liquid, of density 1·502 at 18° C., and according to KOPP boils at 98°·6 C. It has a peculiar pungent odour. Chloral is readily soluble in ether, and when mixed with a small quantity of water or alcohol solidifies to a mass of crystals of the hydrate or alcoholate. When kept for some time, or when placed in contact with concentrated sulphuric acid, it is converted into a metameric compound ($C_6H_3Cl_9O_3$) called metachloral. In the latter process of transformation it is accompanied by a little chloralide, from which it may be freed by pulverising it and washing it with alcohol. Aqueous solutions of the alkalies readily decompose chloral with formation of chloroform and potassium formate:—

$$\underset{\text{Chloral.}}{CCl_3.CHO} + KHO = \underset{\text{Chloroform.}}{CHCl_3} + \underset{\text{Potassium Formate.}}{CHO.KO}.$$

In fact, this is the best method known of preparing absolutely pure chloroform. When heated with

alcoholic potash, chloroform and ethyl formate are produced, the reaction taking place wholly between the alcohol and the choral—

$$\underset{\text{Chloral.}}{CCl_3.CHO} + \underset{\text{Alcohol.}}{C_2H_5.OH} = \underset{\text{Chloroform.}}{CHCl_3} + \underset{\text{Ethyl Formate.}}{CHO.C_2H_5O.}$$

Alcohol alone, however, does not effect this decomposition.

Chloral is converted into aldehyde by the action of nascent hydrogen, as when it is treated with zinc and dilute sulphuric acid, the 3 atoms of chlorine being replaced by hydrogen. Chloral, or its hydrate, when boiled for some time with nitric acid is decomposed, giving rise to chloropicrin, CCl_3NO_2; but at the ordinary temperature trichloracetic acid is produced. By far the most convenient method of preparing this acid, in fact, consists in exposing a mixture of chloral hydrate with three times its weight of fuming nitric acid to the sunshine for three or four days, and then distilling the mixture. At 195° C. pure trichloracetic acid comes over.

Chloral, when treated with different reagents, undergoes numerous and varied decompositions, but as these are purely of scientific interest, we must refer our readers for a full account of them to Watts' "Dictionary of Chemistry," 2nd Supp., p. 308, *et seq.*

Chloral unites directly with various substances, but the only compounds of any technical interest are the hydrate and alcoholate.

Chloral Alcoholate, $C_4H_7Cl_3O_2$, or $CCl_3.CH(OC_2H_5)(OH)$, may be obtained in a pure state by mixing the equivalent quantities of anhydrous chloral and absolute alcohol. The two substances combine with the evolution of much heat, and on standing solidify to a crystalline mass, which, according to Lieben, melts at 43° to 46° C. and boils at 115° C. (113°·5 corr., according to Jungfleisch, Lebaigne, and Roucher). As previously noticed, chloral alcoholate is the ultimate product of the action of chlorine on alcohol. On passing carefully dried chlorine into alcohol until its weight has been doubled, and allowing the product to cool, it solidifies to a crystalline mass, which was thought by Roussin to be chloral hydrate, but has since been proved to be chloral alcoholate. It differs from the hydrate in many respects, as according to Roussin it melts at 46° C. and boils at 115° C. Its behaviour, moreover, when gently heated with nitric acid of specific gravity 1·2, serves readily to distinguish the alcoholate from the hydrate. The former undergoes violent decomposition, whilst the latter is scarcely acted on: the alcholate also is readily soluble in cold chloroform, whilst the hydrate is not.

Chloral Hydrate, $C_2H_3Cl_3O_2$, or $CCl_3.CH(OH)_2$, is readily prepared by a process similar to that employed for the alcoholate, namely, by mixing chloral and water in equivalent proportions. The mixture becomes heated and solidifies to a mass of crystals of the hydrate. These are soluble in a larger quantity of water, but the solution when evaporated *in vacuo* over concentrated sulphuric acid deposits the hydrate again in large rhombic plates. According to Flückiger, it crystallizes in splendid flat tables from warm oil of turpentine; but the best method of purifying it is to recrystallize it from pure boiling bisulphide of carbon, which takes up about 20 per cent. of its weight. On cooling, the greater portion is deposited in beautiful, transparent, oblique rhombic prisms, which, after being exposed to the air to allow the adhering bisulphide to evaporate, boil at 97°·5. The hydrate when dissolved in water produces a considerable fall of temperature. Many organic bases, such as quinine, cinchonine, strychnine, aconitine, and atropine, dissolve in a concentrated aqueous solution of chloral hydrate. It also dissolves camphor and phenol.

Manufacture.—Chloral is always manufactured by passing chlorine into alcohol, but the details of the process and of the methods adopted for its purification and conversion into the crystalline hydrate vary to some extent. An excellent result is obtained by passing a rapid stream of chlorine into 120 to 150 lbs. of alcohol, of at least 96 per cent., contained in a large stoneware vessel. The current of gas must be continued day and night without intermission, until the temperature of the chlorinated alcohol has risen to from 60° to 75° C., and its density is 41° Baumé. The product is now transferred to a copper vessel lined with lead, capable of holding 30 to 40 gallons, and an equal weight of concentrated sulphuric acid gradually added. If the mixture be now heated to boiling, hydrochloric acid is copiously evolved, whilst the chloral condenses in the cohobator adapted to the head of the copper vessel and flows back again. The application of heat is continued as long as hydrochloric acid is evolved, which usually continues for seven or eight hours. By this means the chloral alcoholate and other impurities are completely decomposed or destroyed. The cohobator is now replaced by a bent tube fitted with a thermometer, and connected with a worm in order to distil off the purified chloral. When the temperature, which is at first 95° C., rises to 100° C., the distillation is interrupted, all the chloral having passed over. The small amount of free hydrochloric acid still present in it is now neutralized with chalk, and the chloral submitted to a final rectification. In order to convert it into the hydrate 17½ ounces of distilled water are added to each 9 lbs. of pure chloral, and the mixture agitated, taking care to cool during the operation. The still fluid hydrate may now be poured into shallow earthenware dishes, where in the course of half an hour it solidifies into thin cakes, or it may be crystallized from chloroform. For this purpose it is mixed with about half its bulk of chloroform, and put aside in a cool place. In eight or ten days, when the crystallization is complete, the crystals are freed from the mother liquor by a centrifugal machine, and dried at a gentle heat. The mother liquor may be used for crystallizing fresh quantities of the hydrate.

Chloral hydrate was introduced by Liebreich as an anæsthetic and hypnotic, and is now very extensively used in medicine, enormous quantities being manufactured for that purpose, especially in Germany.

Valuation of Chloral Hydrate.—As the specimens of chloral hydrate met with in commerce vary to a considerable extent in the actual amount of chloral they contain, it becomes important to have a simple and accurate method of determining their value. Several processes have been proposed for this purpose; those usually employed consisting in decomposing the chloral by ammonia or a fixed alkali. WOOD recommends for this purpose distilling it with water and milk of lime, and collecting and weighing the chloroform which comes over after separating it from the water. The amount of pure chloral in any specimen of chloral hydrate may also be easily determined by taking advantage of the readiness with which it is decomposed in the cold by an aqueous solution of potassium hydrate. For this purpose 25 grammes of the chloral hydrate under examination are introduced into a tube graduated to $\frac{1}{10}$ cubic centimètres, and then a solution of potassium hydrate is gradually and cautiously added, in quantity rather more than sufficient to decompose the product, supposing it to be the pure hydrate. Whilst the alkali is being added, the tube must be well cooled, as the action is violent at first. As soon as it has somewhat subsided, the decomposition may be completed by gently inclining and finally shaking the tube. In the course of an hour or two the liquid will become clear and separate into two layers. That at the bottom is the chloroform, which can be measured and the percentage of chloroform calculated from its known specific gravity, due regard being paid to the temperature.

The decomposition of the chloral by alkalies does not, however, give perfectly accurate results, as chloroform is not only slightly soluble in water, but also takes up water. VERSMANN, for this reason, prefers to decompose the chloral hydrate with sulphuric acid: 5 or 6 c.c. of concentrated sulphuric acid are introduced into a graduated tube capable of being closed with an accurately fitting stopper, and heated by immersing it in water at 60° C.; 10 grammes of the chloral hydrate are then added, the whole well shaken, and put back into the hot water for a few minutes. The decomposition is immediate, and as soon as the tube has been taken out and allowed to cool, the amount of pure chloral which floats on the acid may be read off. In comparative experiments, somewhat higher results are obtainable by this method than when the amount of chloral is estimated from the chloroform produced.

CHLOROFORM, *Trichloromethane*, or methenyl chloride ($CHCl_3$) (French *Chloroforme*).—This compound was discovered by LIEBIG in the year 1830, whilst studying the products which are formed by the action of chlorine on alcohol, and independently by SOUBEIRAN a short time afterwards. The latter obtained it by the action of chloride of lime on alcohol, and although it is now almost invariably prepared on the large scale by this method, it is also formed in many other chemical reactions: for instance, by the action of chlorine on marsh gas, and on gaseous methyl chloride; when chloral or trichloracetic acid is treated with an alkali; and by the action of chloride of lime on amylic alcohol, acetone, oil of turpentine, acetic acid, tartaric acid, and phenol.

Chloroform may easily be prepared on a small scale by SIMEELING'S process. This consists in distilling in a retort, whose capacity should be at least twice the bulk of the materials, a mixture of eight parts of good chloride of lime, one of quick lime, forty of water, and one of alcohol. A gentle heat should be applied, and the chloroform which comes over separated from the supernatant layer of water. It should then be agitated with concentrated sulphuric acid, and rectified. The weight of the chloroform obtained is nearly equal to one-third of that of the alcohol employed.

When perfectly pure, chloroform is a colourless limpid liquid, which refracts light strongly, and has a peculiar pleasant odour and sweet somewhat burning taste. According to REGNAULT its specific gravity at 17° C. is 1·491, and it boils at 70°. It does not ignite on the application of a light, but when mixed with alcohol it burns with a smoky flame, edged with green. It is only very slightly soluble in water, but imparts to it a sweet taste. It is soluble in all proportions in alcohol and ether.

Chloroform, having the above specific gravity, has a very remarkable peculiarity, namely, that the addition of one, two, three, four, or five per cent. of alcohol renders it opaline; if the proportion is augmented to ten per cent. it again becomes perfectly limpid, but at the same time the density is considerably diminished. Many organic bases, camphor, caoutchouc, wax, amber, copal, and all the common *resins* readily dissolve in it. With black and red sealing-wax it makes a strong varnish. It dissolves sulphur and phosphorus slightly, iodine and bromine more freely, forming deep-red solutions; it coagulates albumen; it floats on concentrated sulphuric acid, which is only darkened by it at a boiling heat. Nitric acid very slowly decomposes it in the cold, but if the temperature is raised, it is oxidized with evolution of nitrous fumes. When chloroform is heated with an alkaline cupric solution, such as is obtained by adding caustic potash in slight excess to a solution of cupric sulphate and potassic tartrate, a precipitate of cuprous oxide is formed. This reaction is very delicate, but the most characteristic and sensitive test for chloroform is the formation of phenyl carbamine, $C_6H_5.CN$, as proposed by HOFMANN. If a little aniline and an excess of an alcoholic solution of potassic hydrate are added to a liquid in which even a mere trace of chloroform is present, and the mixture gently heated, the peculiar penetrating odour of the carbamine will be at once perceived. Of course compounds which, like chloral, are decomposed by an alkali with formation of chloroform, give the same reaction. It has no bleaching properties; it does not affect iodide of potassium, nor does it dissolve gold, either *per se* or when boiled with concentrated nitric acid. Nitrate of silver occasions no precipitate with an alcoholic solution of chloroform. It leaves intact chloride of gold, even when boiled with it.

The vapour of chloroform, passed over copper or

iron heated to redness, is decomposed, giving rise to a metallic chloride and a deposition of carbon: according to BERTHOLLET acetylene, C_2H_2, is simultaneously produced. Pure chloroform can be distilled off potassium or sodium without change, but when the metal is heated in the vapour, decomposition takes place with explosive violence. It is scarcely decomposed by boiling with an aqueous solution of potassic or sodic hydrate; an alcoholic solution, however, acts quickly, a formate and chloride of the alkali metal being obtained,

$$\underset{\text{Chloroform.}}{CHCl_3} + 4\,KHO = \underset{\text{Potassic formate.}}{CHO.KO} + 3\,KCl + 2\,OH_2.$$

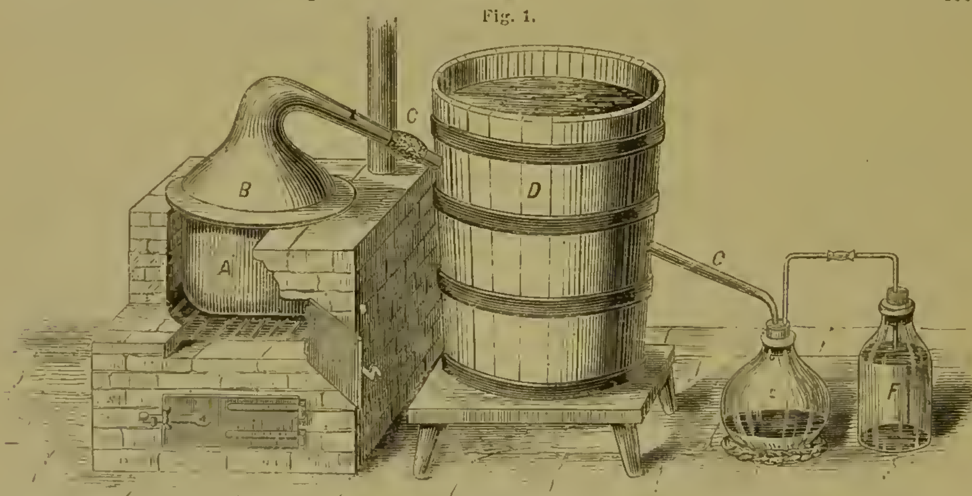
When chloroform, $CHCl_3$, is heated in a current of chlorine, in sunlight, or is treated with iodine chloride, or with antimonic pentachloride, the last atom of hydrogen is replaced by chlorine, and carbon tetrachloride or tetrachloromethane, CCl_4, is formed.

According to PERKIN, when an alcoholic solution of chloroform is agitated with zinc powder and a little ammonia, the chloroform is reduced, and METHYLENE DICHLORIDE, CH_2Cl_2, is found amongst the products; it may be separated by fractional distillation. This compound is also produced by treating methylene di-iodide with chlorine, and along with chloroform and carbon tetrachloride, when chlorine acts on methylic chloride in sunshine. (PERKIN, *Jour. Chem. Soc.*, xxii. 260, and *Chem. News*, xviii. 106). It is a colourless liquid, having an odour similar to that of chloroform, and a burning taste. It boils at about 40° C., and its density at 0° is 1·3604. It has been proposed as an anæsthetic agent, but has not come into general use.

Chloroform, $CHCl_3$, may be regarded as methane or marsh gas, CH_4, in which three atoms of the hydrogen have been replaced by chlorine. Its composition is the following:—

C	= 12	10·04
H	= 1	0·84
Cl_3	= 106·5	89·12
	119·5	100·00

Fig. 1.



MANUFACTURE.—Chloroform is almost universally prepared on the large scale by heating chloride of lime with alcohol, but the details of the process vary considerably. The following are some of the best known methods for the manufacture of this substance:—

1. 130 lbs. of chloride of lime (bleaching powder) and 7 lbs. of ordinary lime, with sufficient water to form a paste, are introduced into a capacious alembic of common earthenware. When well stirred together, more water is added, with 25 lbs. of rectified spirit of wine. Care must be taken that the still is not more than half full; after the head is well luted, a gentle steam heat is applied, and the chloroform distils over along with a little dilute alcohol.

2. 100 lbs. of fresh chloride of lime are thoroughly mixed with 40 gallons of water, so as to form a thin cream, and then introduced into the still, A, Fig. 1, which it should not more than half fill; 12½ lbs. of 90 per cent. alcohol are now poured in, and the head, B, luted firmly on and connected air-tight with the worm, C C, the other end of which passes into the receiver, E. After allowing the apparatus to remain for twelve hours, the retort is gently heated; a powerful reaction soon commences, which requires careful watching at first, for if too great heat be applied, the contents of the retort may boil over. As soon, however, as it has somewhat subsided and the chloroform ceases to come over rapidly, the heat should be increased until the liquid boils, and nothing but water distils. The whole operation requires about four or five hours, and yields 7 lbs. of crude chloroform. This is mostly in the receiver, E, a small portion only being found at the bottom of the bottle, F, which is three parts filled with cold water.

3. In KESSLER's method, 80 lbs. of the strongest chloride of lime are introduced into a large leaden cylinder through an opening in the top, by means of a square wooden funnel, provided near its lower extremity with a pair of horizontal rollers; these when turned serve to drive the chloride quickly into the still. 8 lbs. of slaked lime are then introduced in a similar manner, and afterwards 20 gallons of water, at a temperature of 90° C. The apparatus is now carefully luted, and the contents

well mixed by means of a revolving fan fixed in the interior of the cylinder. When the contents are thoroughly incorporated, 8 lbs. of alcohol are poured in through an opening provided for that purpose, together with the residues of former operations, and if the action does not immediately commence, steam is blown in by means of a pipe reaching to the bottom of the still. As soon as the chloroform begins to distil the steam is shut off, but is again admitted when the action slackens, the mixture being well stirred by means of the fan. When about 5 pints have been distilled over, no appreciable amount of chloroform remains in the retort.

The chloroform obtained by any of the above processes, after being separated from the supernatant layer, is washed several times with a dilute solution of sodic carbonate, and then distilled once or twice off concentrated sulphuric acid. The aqueous liquid separated from the chloroform contains alcohol, and should be employed, along with fresh alcohol, in a future operation.

4. A very pure chloroform is now manufactured from chloral by decomposing it with an alkali. Chloroform is scarcely acted on by an aqueous alkaline solution, whilst chloral readily splits up under these circumstances, producing chloroform and an alkaline formate;

$$\underset{\text{Chloral.}}{C_2HCl_3O_2} + \underset{\text{Potassic hydrate.}}{KHO} = \underset{\text{Chloroform.}}{CHCl_3} + \underset{\text{Potassic formate.}}{CHO.KO} + OH_2.$$

If, therefore, chloral hydrate is heated with a dilute solution of potash or soda, it is decomposed in the manner just pointed out, and the chloroform distils over, accompanied by a little water. After being separated from the latter, and distilled off concentrated sulphuric acid, it is perfectly pure.

For the introduction of chloroform as an anæsthetic agent, mankind is indebted to Dr. SIMPSON of Edinburgh; great care, of course, must be taken to insure its purity, for the oils which accompany it when first formed are very injurious. In administering it, some person should be especially appointed to watch the pulse and respiration of the patient, and remove the chloroform if necessary; but it should never be employed in cases where there is disease of the heart, or a marked tendency to apoplexy. Doubtless many accidents and even deaths occur, not from the effects of the chloroform itself, but from the poisonous action of the deleterious oils and other adventitious matters contained in that which is sold. Although this source of danger might be entirely avoided by employing chloroform prepared from chloral, yet medical men ought to exercise caution in administering to sufferers even the purest preparation.

ADULTERATION.—It is to be deplored that a substance of so much value as chloroform should, in many instances, be rendered positively dangerous or even fatal, by the presence of impurities that might be easily avoided in the first instance, or subsequently removed, but which contaminate it, sometimes to such an extent as to render it either inefficacious for good, or most deleterious when administered.

The foreign ingredients most frequently met with are alcohol, aldehyde, hydrochloric and hypochlorous acids, and chlorinated oils. The latter are exceedingly poisonous in their action; and, moreover, there is considerable difficulty in discovering their presence, and in freeing chloroform from them. Alcohol may be detected by adding one or two crystals of chromic acid to two drachms of the suspected liquid; should it be present, the chromic acid is soon reduced to the state of the green sesquioxide of chromium. The same result is obtained by adding a little bichromate of potassa and sulphuric acid, instead of the chromic acid.

BESNOU gives the following as the best method of applying this test:—He takes a few milligrammes of powdered bichromate, and puts it into a test tube five or six inches long, and rather more than half an inch in diameter; he next adds four or five drops of concentrated sulphuric acid, and stirs with a glass rod until the chromic acid is liberated; then adds three or four drops of water, to dissolve the chromic acid; and lastly, pours in three or four centimètres of chloroform—one, to one and a half inch cubic measure—shakes quickly for twenty seconds, and leaves the whole to repose; very soon the deep green colour of the chloride of chromium appears, if the proportion of alcohol amounts to five per cent., and is deposited in a distinct layer at the bottom, whereas the upper part is barely coloured a very pale green. *If the chloroform be pure, the mass is scarcely tinged of a greenish yellow, and there is no separation of any layer.* If it has been adulterated with ether, the results are precisely similar.

ROUSSIN has proposed to use dinitrosulphide of iron as a test for the presence of alcohol, ether, or wood spirit in chloroform; if any of these impurities are present it acquires a dark colour, but remains colourless if pure. Dinitrosulphide of iron is prepared by slowly adding ferric sulphate to a boiling mixture of ammonic sulphide and potassic nitrite, as long as the precipitate at first produced continues to redissolve, and then filtering the solution. According to HARDY metallic sodium does not act on pure dry chloroform, but if alcohol or wood spirit are present, marsh gas and hydrogen are given off.

Dr. LETHEBY thinks that much of the chloroform used in America is contaminated with alcohol; for it has the low specific gravity of 1·45. This also may be one of the reasons for the unsatisfactory accounts which have come from that country of its bad and variable effects.

Aldehyde is recognised by its reducing action on the hydrated oxide of silver, and by its rendering *aqua potassæ* of a brown colour when heated with it.

Hydrochloric acid is a very common impurity in chloroform, and often exists in it to a very considerable extent. That containing this acid has often an irritating odour; it reddens litmus paper, and affords, when shaken with a solution of nitrate of silver, a white precipitate.

Hypochlorous acid may be recognised by its odour, as also by its reddening, and then partially bleaching, a piece of litmus paper.

Chloroform from wood spirit is much less pure than that prepared from alcohol, but in both cases more or less of certain chlorinated oils are present, which can only be removed by agitation with, or by distillation from concentrated sulphuric acid. According to GREGORY, impure chloroform may be recognised by the disagreeable odour which is left on a cloth moistened with it after it has evaporated, and by the yellow or brown colour it imparts to oil of vitriol when agitated with it. Pure chloroform placed upon oil of vitriol produces a contact surface convex downwards; impure chloroform gives a plane contact surface. Chloroform prepared from chloral is purer than even the best specimens made by the ordinary process; it is not affected by light, and when allowed to evaporate spontaneously, the last few drops have the same odour as the pure substance, instead of the unpleasant smell which can be distinctly observed with ordinary chloroform, even after purification with concentrated sulphuric acid.

The presence of these chlorinated compounds to any appreciable extent in chloroform, produces a marked effect upon the system. They occasion a peculiar throbbing headache, and a rapid prostration of the vital powers. These symptoms may often be observed when the chloroform is only inhaled for a short time; and there can be no doubt that they are very often the causes of the discomfort so often resulting from the use of certain samples of this anæsthetic.

The above-mentioned methods are more or less useful for ascertaining the actual purity of chloroform, *but none of them* indicate the proportion of the sophistication. The presence of alcohol is the most common, either from negligence in the rectification, or from after addition. M. BESNOU has endeavoured to find an easy method of determining the quantity, by the use of the densimeter, and the areometer for acetometry.

He operated upon mixtures in various proportions, and compared their densities. These are appended under the form of a table which will enable the reader at once to follow the differences. It is from 100, as indicating perfect purity, to 75 of chloroform, or from 0 to 25 per cent. of alcohol in the liquid. In this table, *absolutely* pure anhydrous chloroform is not alluded to, but only the commercial product, and such as may be obtained by the ordinary operation of its manufacture:—

Real density.	Corresponding degree of the areometer.	Proportion of alcohol of specific gravity 1·35 mixed with it.	Ponderable quantity of alcohol per cent.
1·4945	47·60	—	0·00
1·4908	47·38	1	0·50
1·4874	47·16	2	1·00
1·4845	46·94	3	1·50
1·4772	46·47	5	2·50
1·4602	45·40	10	5·00
1·4262	43·00	20	10·00
1·4090	41·82	25	12·50

The diminution of the specific gravity by each per cent. of alcohol mixed with it at 4·°5 C., is consequently ·0034, whence it results, that chloroform mixed with ten per cent. of alcohol loses thirty-four degrees of the densimeter, and with twenty per cent. sixty-eight degrees; thus the density being determined by the areometer for specific gravity, to estimate the mixture it will only be necessary to divide the known difference by ·0034.

CHLORINE.—French, *chlore;* German, *chlor.*—This body was discovered by SCHEELE in 1774, and further investigated by GAY-LUSSAC, THÉNARD, and, above all, DAVY, who established its elementary character and gave it the name it now bears, which is derived from χλωρος, yellowish-green, the colour the gas possesses.

It is obtained by heating aqueous hydrochloric acid with peroxide of manganese. The acid is a solution of hydrochloric acid gas—a compound of chlorine with hydrogen—in water. The peroxide of manganese is an oxygen compound of the metal manganese. The reaction which takes place in the operation is symbolically expressed by the following equation:—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$$

The first result of the action is, indeed, tetrachloride of manganese, $MnCl_4$, thus:—

$$MnO_2 + 4HCl = MnCl_4 + 2H_2O,$$

but the tetrachloride, being a very unstable compound, soon breaks up into chloride of manganese and free chlorine, $MnCl_2$ and Cl_2, and thus the final result of the reaction is expressible through the first equation.

It may also be prepared by heating together common salt, manganese peroxide, and sulphuric acid—

$$MnO_2 + 2NaCl + 2H_2SO_4 = MnSO_4 + Na_2SO_4 + 2H_2O + Cl_2.$$

But the process represented by this reaction demands too high a temperature, and the best proportion for good practical results is expressed by the equation:—

$$MnO_2 + 2NaCl + 3H_2SO_4 = MnSO_4 + 2NaHSO_4 + 2H_2O + Cl_2.$$

In this country all chlorine is prepared from hydrochloric acid, which is obtained in enormous quantities in the course of the salt-cake manufacture.

Chlorine gas has, according to BUNSEN, a specific gravity of 2·4482. A pressure of four atmospheres reduces it to a bright yellowish liquor of spec. grav. 1·33; the same liquid state is reached by exposing it to a temperature of 72° Fahr. It possesses a strong, suffocating odour. The readiest protection in an atmosphere charged with chlorine is to place a sponge saturated with spirit of wine over the mouth and nose; if the gas has already been inhaled to some extent, steam ought to be drawn into the lungs, or, according to BOLLEY, the vapours of aniline.

Chlorine combines with every other element except fluorine, and its affinity for some of the metals is very great; antimony, zinc, and several others, showered in powder into it, take fire and produce a brilliant combustion.

Metallic oxides heated in chlorine become chlorides: lime heated thus becomes chloride of calcium with liberation of oxygen.

A mixture of equal volumes of chlorine and hydrogen explodes, when exposed to sunlight, with violence, and the result of the union of the two elements is hydrochloric acid. The combination of the two gases can be effected without explosive violence by bringing the mixture under the influence of diffused daylight. Spongy platinum, or the electric spark, leads likewise to the union of the two elements.

Mixed with marsh gas (CH_4) chlorine burns with a pale green flame, forming hydrochloric acid, whilst the liberated carbon is deposited as soot.

Chlorine is soluble in cold water. With water cooled to near the freezing point it forms a crystalline compound of the composition $Cl\ (H_2O)_5$. Its solubility in water varies with the temperature, 1 volume of water absorbs—

VOLUMES OF GAS.

	According to PELOUZE.	According to GAY-LUSSAC.
At 32° Fahr.	1·75—1·80	1·43
" 43½° "	—	2·08
" 47° "	—	3·04
" 50° "	2·75	3·00
" 53½° "	2·55	—
" 62½° "	—	2·37
" 86° "	2·00—1·10	—
" 95° "	—	1 61
" 104° "	1·55—1·60	—
" 122° "	1·15—1·20	1·19
" 158° "	0·60—0·65	0·71
" 212° "	—	0·15

The aqueous solution of chlorine decomposes readily when left exposed to the light; hydrochloric acid is formed with elimination of oxygen.

Formerly aqueous solution of chlorine was employed, especially in France, for bleaching purposes; at present it is entirely out of use.

Chlorine acts powerfully upon all vegetable and animal substances, and its action consists in combining with some (or sometimes the whole) of the hydrogen, which is a never absent constituent of all animal and vegetable tissues. Upon this property of chlorine rests its application in bleaching.

Chlorine forms four compounds with oxygen and hydrogen, which are ordinarily called acids, but which we prefer to consider, with Professor WILLIAMSON, as salts in which the place of the metal is occupied by hydrogen. The four compounds are :—

Hydric hypochlorite (usually, hypochlorous acid), $HClO$.—It is obtained by shaking up chlorine water with mercuric oxide, insoluble oxychloride of mercury and a dilute solution of hydric hypochlorite being formed; the latter can be somewhat concentrated by evaporation, but not without decomposition of the acid. The aqueous solution is colourless, and has a peculiar sickly odour. It is an exceedingly weak acid, being expelled by carbonic acid from its salts in presence of water. It has strong bleaching properties, and is present together with hydrochloric acid in the solution of chlorine in water. This can be shown by adding a solution of silver nitrate to the chlorine water, as long as any precipitate is formed, and filtering: the filtrate, from which the chlorine of the hydric chloride had been removed, shows all the bleaching power which the solution had before the addition of the silver salt.

On passing chlorine into a cold dilute solution of caustic potash, chloride of potassium and potassic hypochlorite are first formed—

$$2KOH + Cl_2 = KCl + KClO + H_2O.$$

On continuing the treatment with chlorine, the hypochlorite passes into the chlorate. This latter result is also arrived at by conducting chlorine gas into a hot or a concentrated solution of caustic potash.

A cold dilute solution of carbonate of potash leads, on being acted upon by chlorine, through two preliminary stages to the formation of potassic chloride and hypochlorous acid proper, Cl_2O, the so-called anhydrous acid.

Hydric chlorite (usually, chlorous acid), $HClO_2$.—It is formed by treating potassic chlorate, in the presence of hydric nitrate, with some reducing agent, as sugar, tartaric acid, &c. It is a greenish-yellow permanent gas of 2·65 sp. gr.; water dissolves ten times its own bulk of the gas. Heated to about 135° Fahr. it explodes.

Hydric chlorate (usually, chloric acid), $HClO_3$.—It is best prepared by adding dilute oil of vitriol to a solution of barytic chlorate, in quantity exactly sufficient to combine with all the barium, without leaving any sulphuric acid mixed with the hydric chlorate. Barytic sulphate is completely precipitated—

$$Ba(ClO_3)_2 + H_2SO_4 = BaSO_4 + 2HClO_3.$$

Its potassic salt forms, as already mentioned, when chlorine is passed into a hot concentrated solution of caustic potash—

$$6KOH + 6Cl = 5KCl + KClO_3 + 3H_2O.$$

Potassic chlorate is also formed by heating a solution of potassic hypochlorite—

$$3KClO = KClO_3 + 2KCl.$$

The aqueous solution of hydric chlorate may be concentrated by first evaporating at a temperature not exceeding 100° Fahr., and then completing the process by putting the partially concentrated acid into a vacuum over some strong oil of vitriol.

Hydric chlorate is a powerful oxidising agent: a piece of paper soaked with it takes fire in the air. Hydric chlorate itself is not explosive; but its salts, mixed with combustible bodies like charcoal, sugar, sulphur, &c., explode readily.

All its salts are readily soluble in water.

Hydric perchlorate (usually, perchloric acid), $HClO_4$.—It may be obtained by distilling at gentle heat potassic perchlorate with oil of vitriol; treating the distillate with argentic sulphate for the purpose of taking away free chlorine; decanting, adding barytic carbonate to fix the sulphuric acid, and again distilling with care. At first a very dilute acid comes over, but when the temperature has risen to 392° Fahr., a liquid of sp. gr. 1·65 passes—it is collected into a new receiver. This acid is a colourless liquid, which slightly fumes in the air. It may be still further concentrated by distilling it with four to five times its weight of sulphuric acid, when the greater part

of it is decomposed into chlorine and oxygen, but a portion condenses in a mass of small crystals, and also in long four-sided prismatic needles, which settle in the neck of the retort. SERULLAS considers the two as different hydrates of hydric perchlorate.

A simpler mode of preparing it is to decompose the solution of potassic perchlorate by hydrofluosilicic acid: the potassium is carried down as fluosilicate, while hydric perchlorate remains in solution—

$$2KClO_4 + H_2SiFl_6 = K_2SiFl_6 + 2HClO_4.$$

The potassic perchlorate is obtained by fusing the chlorate, and continuing to heat it, until the evolution of oxygen has ceased; the remaining mass consists of potassic chloride and potassic perchlorate.

The perchlorate is the most powerful of the acids of chlorine; a dilute solution of it dissolves zinc and iron with evolution of hydrogen and formation of the perchlorates of these metals.

The bleaching properties of chlorine were first suggested by BERTHOLLET in a paper read to the French Academy in 1785. In 1787 Professor COPELAND and the Duke of GORDON commenced works in Aberdeen to make chlorine in large glass (WOOLF'S) apparatus, which was afterwards improved by the apparatus being made of hard wood. Bleaching by means of chlorine was introduced into Glasgow in 1789 by Mr. WATT, the well-known engineer, and from thence it soon found its way into Lancashire. As the demand for chlorine increased, the apparatus for its production was enlarged, and a vessel made of strong lead, fixed in a metal jacket, was substituted, a stone agitator being used to mix the charge of salt, manganese, and sulphuric acid.

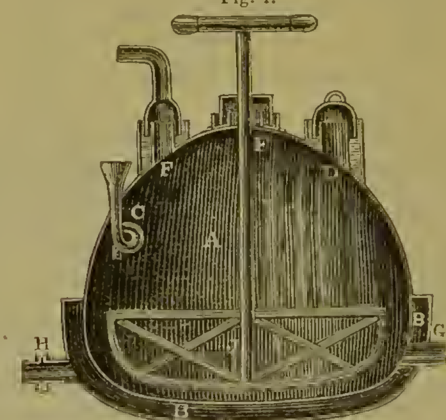
The first mode of using chlorine in bleaching was to transmit it through water till the latter was saturated; into this solution the goods were put, and heat was then applied to bring the chlorine to act upon the colouring matter. JAVELLE in 1790 suggested that a little caustic potash should be added to the water, and this plan was adopted in Liverpool, where a small work was commenced in 1792.

Great inconveniences attended this method of bleaching, and, as an improvement upon the system, the solution was diluted, and it was found to effect the decoloration equally as well as the strong liquor, without causing the many injuries which the latter occasioned. In consequence of the cloth becoming yellow after being bleached, recourse was had to alternate boiling in alkaline liquors, after the immersion in the bleaching medium; but the frequent exposure of the goods, as well as of the vessels containing the bleaching liquor, caused the liberation of too much chlorine, which proved a great impediment on account of its injurious effects upon the operatives, and hence the process could not be carried out. In the meantime, however, the fact was discovered that alkalies combine with more chlorine than water, retain it with more tenacity, and yield it more regularly to the colouring matter. The workmen now had more security: for the gas, being in chemical combination with the alkali, did not escape into the atmosphere, although this combination did not prevent it from operating upon the goods.

The next improved step in the application of chlorine was the use of lime instead of the alkalies; but the first methods of using it, namely, of steeping or passing the goods through lime water and then exposing them to the action of chlorine, were productive of some irregularities, which required a further improvement in the preparation. This improvement was accomplished by CHARLES TENNANT of Glasgow, who impregnated the lime water with chlorine, and took out a patent for his *bleaching liquor* in 1798. This was followed by one in 1799, according to which dry lime was employed for the absorption of the chlorine, and the product obtained, *bleaching powder*, has remained ever since the vehicle for the chlorine used in the bleaching industry. This last improvement is due to C. MACINTOSH, at that time partner in the firm, TENNANT & KNOX, Glasgow.

The vessels used in the older days for preparing chlorine on the large scale, were composed of strong sheet-lead, or partly of lead and partly of iron. Fig. 1

Fig. 1.



represents a section of one of these stills. A is the still: it consists of two parts, the lower one, B, being inclosed in a jacket of cast iron, steam is injected into the intermediate space for the purpose of heating the contents. Sometimes the lower half was constructed of cast iron, having a groove in the upper part, to which the top part was secured by a coat of good cement. In this case, heat was communicated by means of a slow fire placed under the cast-iron bottom. In the dome of the still there were four openings: into one, C, the solid materials employed were introduced, whilst the acid was added through the funnel opening, F. The gas evolved passed off by the pipe, E, to the purifier and chamber, where it combined with the lime, and the shaft of the agitator passed up through D.

Steam was introduced from an ordinary boiler through the pipe, H, and the materials, after the whole had been decomposed, were drawn off by the pipe, G. The four openings, C, D, E, F, were secured by water lutes, capable of bearing a pressure greater than that required in the chamber where the saturation took place.

When operations were carried on, the manganese and salt were introduced in the ratio of 100 parts of the former to 150 of the latter; about 185 of sulphuric acid, spec. grav. 1·6, were then added, and the covers luted on by pouring water into the several receptacles after the lids have been closed. The fire was then lighted, or the steam introduced, as the case may have been, till the temperature of the interior was raised to 180° Fahr., keeping the agitator worked from time to time to raise the manganese, which readily subsides on contact with the acid. In the proportions given above, the equivalents of the pure materials are taken, but commercial peroxide of manganese is never pure, 60 to 75 per cent. being its average value; hence it was necessary to proportion the salt and acid, in the ratio of the above numbers, to the percentage of pure peroxide. Where carbonate of soda or sulphuric acid was manufactured, the hydrochloric acid, which is obtained as a bye-product, was employed for generating chlorine.

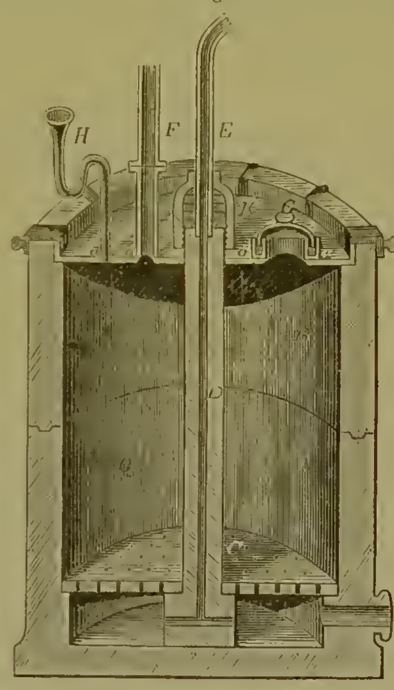
These lead alembics were used for a longer time in France than in this country. In the Mülhausen district they employed for some time large glass globes with long necks, heated upon a sand-bath, for the liberation of the chlorine from hydrochloric acid and manganese. But both forms suffice only for the production of comparatively small quantities of bleaching powder.

A vessel to manufacture chlorine on a large scale, and used, we believe, in Germany, is represented in Fig. 2. It is a cylinder of sandstone, the lower half of which, A, is carved out of a single block; the upper half, B, also of one piece, is joined to the lower by means of a grooved joint, which is filled up with a cement made of clay and boiled linseed oil. About 6 inches above the bottom the cylinder widens by 2 inches, and the rim thus formed bears a perforated bottom, C, upon which the manganese is deposited in large lumps. The tube, D, likewise of stone, passes below the perforated bottom, and is at its other end joined to the steam tube, E; the steam must, therefore, when introduced, enter the cylinder through the perforations of the false bottom. The top of the cylinder is closed by a lead cover, K, which is fastened down by means of iron clamps; this lid has an aperture, G, and the tubes, E, F, H, pass through it; tube E serves, as already stated, for the introduction of the steam; tube F is for the delivery of the chlorine; the bent tube, H, which ends in a funnel, for the introduction of the hydrochloric acid, and the opening, G, for throwing the lumps of manganese into the cylinder. The solution of manganese chloride, resulting from the action of the hydrochloric acid upon the manganese, is removed through J, which is kept closed by a wooden stopper whilst the reaction proceeds.

The decomposing vessels, called *stills*, used in England and Scotland are four-sided chambers. Such a still is usually about 5 to 6 feet square and 3 feet deep, and is constructed of large flags of stone about 6 inches thick. They are grooved and fixed together by a cement formed of tar and ground pipeclay, the sides being secured by strong iron bolts. Inside the still, about 18 inches from the bottom, there is placed a large flagstone, upon which the charge of manganese in small pieces is placed. The still is filled up with hydrochloric acid to within about 12 inches of the top, and this acid usually stands about 24° Twaddle's hydrometer. To facilitate the action a steam-pipe is introduced to near the bottom of the still, and sufficient steam forced in to keep the heat up at the end of the operation to about 150° Fahr.

The chlorine obtained is brought into contact with slaked lime, for the purpose of forming the bleaching compound. The selection and preparation of the lime requires much attention. The limestone for this purpose should be as free as possible from iron and manganese, because they impart to the bleaching powder a dark colour. The presence of considerable quantities of magnesia is said to be disadvantageous,

Fig. 2.



inasmuch as the chloride of magnesium, which forms in the treatment with chlorine, absorbs water from the atmosphere with much more avidity than the corresponding lime compound, and the magnesium hypochlorite, which too is formed under the influence of the chlorine, decomposes very readily; two properties which easily lead to the spoiling of the bleaching compound. This statement is, however, contradicted by experienced manufacturers.

Two kinds of limestone are generally used, one called "clipp," which is brought from France, the other a pure limestone from Buxton.

The limestone having been calcined, and a lime tolerably free from the above defects having been obtained, the latter is slaked with water. The quantity of water used must be neither too much nor too little; in the former case, the hydrate of lime conglomerates into balls when treated with

chlorine, and resists in that state penetration by the gas; in the second case, the absorption of chlorine falls very short from the numbers attainable by careful manipulation. The slaking is performed by watering the pieces of calcined lime, which are spread out in layers of not more than 6 inches in height, with a watering can, and turning them over as soon as they begin to swell and to emit steam. Pieces which appear unaffected after this treatment are immediately removed by the workmen.

When the slaking is finished, the lime hydrate is sieved, in order to separate small pebbles and other impurities. The sieved lime hydrate must then be left for a day or two, before being put into the bleaching powder chambers; it is asserted that lime fresh from slaking is not well adapted for absorbing chlorine. When properly prepared the fine lime should contain about 24 per cent. of water, not chemically united.

The chambers in which the lime is brought into contact with the chlorine are of stone or lead. In England the use of lead is almost general. The size of these chambers varies considerably; it depends entirely on the scale of the manufacturing establishment. They are usually about 60 feet long, by 30 feet wide, and 5 feet high.

The screened lime is spread upon the floor of the chamber in a layer of not more than 6 inches in height. Formerly it was laid on wooden trays, fixed in layers one above another; but experience showed that the former mode of distributing the lime is quite as effective with regard to a rapid absorption of the chlorine. When a rather thick layer of lime is saturated with chlorine, the superficial portion is always inferior in bleaching power to the lower portions.

Before admitting the chlorine into the chamber it is passed through a stoneware bottle, for the purpose of freeing it from water vapours, and also from particles of manganese chloride, which are carried over with the chlorine.

The supply of chlorine to the chambers must be so regulated as to prevent the heat, occasioned by the combination ensuing, from rising above 62° Fahr. But, according to Scheurer-Kestner, an elevation of the temperature to about 130° Fahr., consequent on the absorption of the chlorine, is not disadvantageous to the production of bleaching powder. Application of excess of chlorine, however, diminishes the proportions of available chlorine in the product, apparently in consequence of the formation of chlorite.

When the operation is complete the chambers are left closed, in order to allow the complete absorption of all the gas in them. The unabsorbed chlorine is generally drawn off into a fresh chamber of lime, which quickly absorbs it, or in some cases it is taken to the large chimney. The chamber door is then opened, and the bleaching powder is drawn towards it with wooden rakes; the casks are placed just inside the doorway, and are filled with bleaching powder (technically "packed") by a workman, who enters the chamber for the purpose, having previously tied a wet piece of thick flannel over mouth and nose.

Great care is to be observed in the packing of the powder. In the first instance, it is better to be cooled; exposure to the sun is to be avoided, for bleaching powder that has been, even for a very short time, under the influence of the sun's rays, is quite certain to decompose. The powder has to be packed firmly into the casks, and these must be free from moisture.

Any disregard of these precautions leads to a sudden explosive decomposition of the powder in the cask. The gas which on such occasions is met with has been recognised as oxygen; and the bulk of the bleaching powder is found to consist of chloride and chlorate of calcium.

The maximum amount of chlorine absorbed by 100 parts of hydrate of lime is, according to Graham, 41·3 parts, of which only 39 parts are available for bleaching, the remainder going to form calcium chloride and chlorate. The bleaching powder of commerce, however, averages from 35 to 37 per cent., but a product of a strength of 32 per cent. is considered to be more stable than a stronger one.

All bleaching powder is apt to lose gradually its available chlorine. J. Pattinson has made some experiments with the view of ascertaining the rate of this loss, and he finds that in the warmer season the average loss during a month may rise to 0·86 per cent., whilst in a winter month the loss is not more than 0·26 per cent.

The product of the chambers is, according to the most prevalent view at the present time, a mixture of calcic hypochlorite with calcic chloride, associated with which are free hydrate of lime and traces of calcic chlorate. The reaction between the hydrate of lime and the chlorine may therefore be represented thus—

$$2CaO + 4Cl = CaCl_2O_2 + CaCl_2.$$

The determination of the true nature of bleaching powder has been the object of numerous investigations since C. Mackintosh first prepared it. Originally bleaching powder seems to have been looked upon as simply a combination of chlorine with lime, and hence its name of *chloride of lime*. This view of the constitution of the bleaching agent was taken by Berthollet. But Berzelius, led by certain theoretical speculations, asserted that the chlorine existed in the compound as chlorous acid, and that bleaching powder was calcic chlorite. The subsequent discovery by Balard of hypochlorous acid (hydric hypochlorite) gave support to this view, although hypochlorous acid was substituted for the chlorous. Gay-Lussac, in adopting this theory, showed that bleaching powder gave, on being treated with a dilute mineral acid, hydric hypochlorite, which could be isolated by submitting the mixture to distillation by gentle heat.

This liberation of hydric hypochlorite from bleaching powder explains the action of the latter in the bleaching process. It was stated in the description of the operation of bleaching (See Bleaching) that on immersing the fabric in the solution of bleaching powder no bleaching effect, or at least none worth

speaking of, shows itself; but the subsequent exposure of the cloth to the action of an acid leads to the desired decolorisation of the fibre. The chemical change which takes place in the treatment with acid is supposed to be the following:—

$$\underset{\text{Calcic hypochlorite.}}{CaCl_2O_2} + \underset{\text{Hydric sulphate.}}{H_2SO_4} = \underset{\text{Calcic sulphate.}}{CaSo_4} + \underset{\text{Hydric hypochlorite.}}{2(HClO)}.$$

But the decomposition does not stop here; the hydric hypochlorite breaks up into chlorine and oxygen; the latter oxidises the metal of the calcic chloride, and thus sets additional chlorine free—

$$CaCl_2 + CaCl_2O_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + 2Cl_2.$$

But the view expressed above as to the true nature of bleaching powder is not the only one entertained by chemists. E. MILLON viewed it as an oxychloride of calcium, $CaOCl_2$, analogous to calcium dioxide, which view was also taken by J. S. MUSPRATT.

A sample of bleaching powder analyzed by F. ROSE, under the direction of FRESENIUS, yielded 26·72 per cent. of calcic hypochlorite, 25·51 calcium chloride, 23·05 calcic oxide, and 24·72 combined and hygroscopic water. On repeatedly triturating it with fresh quantities of water to a thin pulp, the calcium chloride was found to dissolve at the first trituration, the hypochlorite only at the third. Hence FRESENIUS concludes that the two salts exist in the bleaching powder merely in a state of mixture, or at most as a loose combination easily decomposed by water, and he views, therefore, bleaching powder as a mixture of hypochlorite and oxychloride of calcium, $CaCl_2O_2 + (CaCl_2.CaO)2H_2O$. The oxychloride is decomposed by water into chloride and hydrate of calcium.

J. KOLB found that the most concentrated preparation producible by saturating dry calcium hydrate with chlorine contains 38·5 per cent. bleaching chlorine, 45·8 lime, and 24·7 water, corresponding with the formula $Ca_3H_6O_6Cl_4$. In this product, the water and the whole of the lime are essential constituents, which cannot be removed without the breaking up of the compound. Commercial bleaching powder always contains a small excess of water, as well as free lime, which gives it a greater stability, an effect likewise produced by other inactive substances, such as carbonate or sulphate of lime. KOLB agrees with FRESENIUS as to the manner in which dry bleaching powder is decomposed by water.

The difference in the composition of dry bleaching powder and in that of its aqueous solution is best shown by their different behaviour to carbonic acid. The dry compound is entirely decomposed by carbonic acid, with evolution of chlorine, whereas from the aqueous solution even the greatest excess of carbonic acid precipitates only half the calcium as carbonate, and only with separation of hydric hypochlorite, which does not act upon the residual calcium chloride.

Professor ODLING considers bleaching powder as a *compound*, not a *mixture*, of chloride and hypochlorite of calcium, chiefly on the ground that no calcium chloride can be extracted from bleaching powder by means of alcohol, and that bleaching powder is not deliquescent, like mixtures containing calcium chloride are.

CRACE-CALVERT draws, from experiments of his own, the conclusion that bleaching powder consists of 2 parts of chloride and 1 part of hypochlorite of calcium, a conclusion greatly at variance with the results obtained by other investigators.

Quite recently GOEPNER has returned to MILLON's view of the constitution of bleaching powder, basing his opinion principally on the fact, observed by him, that in distilling a mixture of bleaching powder and sulphuric acid, no hydric hypochlorite but chlorine was obtained. But the experimental result noticed by GOEPNER is not borne out by the observation of other chemists, as has been pointed out, amongst others, by SCHORLEMMER.

Various other theories respecting the true constitution of bleaching powder have been brought forward, but we are compelled to be brief on purely speculative matters. We will only mention some of the more prominent writers on the subject—KOLB, RICHE, BOBIERRE, SCHEURER-KESTNER, RICHTERS and JUNCKER, FRICKE and REIMER, and others.

In many cases it is preferred to pass the chlorine into milk of lime, and thus to obtain a bleaching liquor instead of the solid powder. This is especially the case where the bleaching agent is to be used at the place of its production. Figs. 3 and 4 represent the side and the end view of the apparatus employed by the bleachers of Mulhouse for preparing this liquor. The glass balloons, *a a a*, are placed upon sand baths, which are fixed in brickwork and heated by furnace, *b b*, the flue of which circulates around each globe, and terminates in the pipe, *q q*. The manganese, salt, and sulphuric acid, or manganese and hydrochloric acid, are introduced into these vessels, and the gas as it is developed is discharged into the trough, *c*, by glass tubes. This trough is made of a kind of siliceous freestone, well annealed, and covered over with boards coated interiorly and cemented together with bituminous mastic. The cover is fixed into grooves in the walls of the concave part, and secured against chlorine escaping by cement, &c. In the interior of this vessel a horizontal cylinder, having a number of protruding arms with boards attached in the form of a helix, is placed; it is fastened air-tight, and turned by the winch, *e*. The milk of lime is introduced by the funnel, *f*, and the chloride of lime liquor drawn off at *h*.

H. DEACON has proposed to substitute carbonate of lime for the hydrate in the manufacture of bleaching liquor. Chalk or limestone is piled up in a tower, through which the chlorine ascends, whilst water trickles downwards. Or the chalk or limestone may be powdered, made into a milk, and then treated with chlorine in the ordinary apparatus.

We have seen that, in the production of chlorine by the action of manganese upon hydrochloric acid, chloride of manganese is formed, which, as such, has to be withdrawn from the circle of operations. The residual product, or "still-liquor," is, however, by no means a pure solution of manganese chloride,

but contains, in addition to that compound, considerable quantities of ferric chloride and free hydrochloric acid. It was formerly thrown away and constituted a very serious source of river pollution. The nuisance resulting from this mode of disposing of it, together with the high price of manganese ores, have led to many attempts to utilize it, and it is now almost invariably treated for the regeneration from it of peroxide of manganese for use again in the manufacture of chlorine. Indeed, a large part of the chlorine made is produced by means of artificial peroxide of manganese regenerated from the residues of previous operations.

DUNLOP, in 1855, was the first to suggest a practical method for recovering the spent manganese in a form capable of reapplication in the production of chlorine. His method consists in precipitating the manganese in the still liquor by means of calcium carbonate, and decomposing the resulting manganese carbonate by heat. The plan, as still carried on in the factory at St. Rollox near Glasgow, is the following:—The still-liquor is treated with either powdered chalk or milk of lime, to neutralize the free acid and decompose the ferric chloride contained in it, and is then allowed to stand until all insoluble matters have subsided. The clear solution of manganese chloride is then intimately mixed with milk of chalk, and the resulting milky liquid is run into large iron boilers, through each of which passes horizontally an iron shaft, furnished with a number of projecting arms. This shaft having been put into revolution, so as to keep the contents of the boilers agitated, steam is admitted into them under a pressure of from 2 to 4 atmospheres, and by the combined action of heat and pressure the decomposition of the manganese chloride by the calcium carbonate is finished in about four hours. The manganese carbonate is then allowed to subside, the calcium chloride solution is run off, the precipitate carefully washed, and thrown up in heaps on an inclined surface to drain.

Fig. 3.

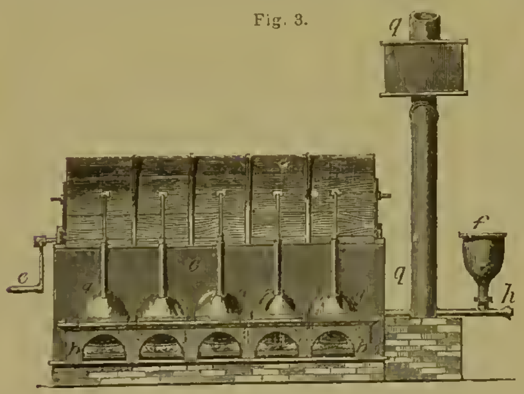
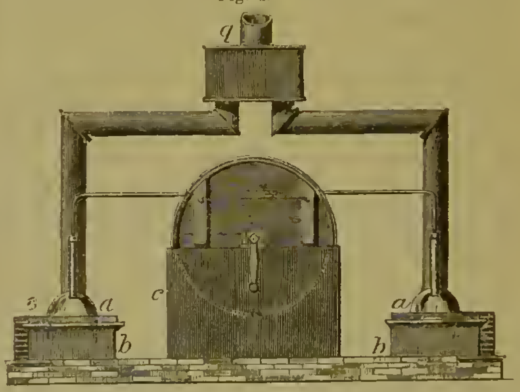


Fig. 4.



The partially dried material is placed in small low waggons of sheet iron, supported on rollers, and slowly drawn through an oven by means of a chain. The oven holds forty-eight of these little waggons. It is 50 feet long, 12 feet wide, and 10 feet high. A fire-brick flue runs down the centre of the bottom of the furnace, and is connected at the far end with two return metal pipes, which lie on each side of the flue. A uniform heat of about 660° Fahr. is maintained in the oven, in which four lines of rails are laid for the small waggons to traverse.

The half-dried material loses all its water and part of its carbonic acid as the waggons pass along the first line of rails, and as they return down the second line, a further escape of carbonic acid ensues, and ultimately the expulsion of all the acid, and the peroxidation of the manganese is completed on the third and fourth lines. This operation lasts about forty-eight hours, and the colour of the material gradually changes from white to brown, and then to black. The ends of the oven are closed by loose hanging doors, so that a sufficient supply of air is always insured. The fire-place is situated below the floor of the oven, and requires the greatest attention.

The product resulting is a mixture of oxides of manganese, containing about 72 per cent. of manganese peroxide.

CLEMM sought to improve this method by substituting magnesium carbonate for the chalk with a view to the recovery of the chlorine, which in DUNLOP'S process is lost in the calcium chloride, since the magnesium chloride yields hydrochloric acid on treatment with steam at a high temperature.

This modification, however, has been found impracticable, and even the original form of DUNLOP'S process has not proved advantageous enough to lead to its adoption by more than a single firm of manufacturers. Messrs. TENNANT still employ it at St. Rollox, but in their new works at Newcastle-on-Tyne recover by H. WELDON'S process, described below.

P. W. HOFMANN attempted the regeneration of the manganese by means of the mixture of calcic polysulphides obtained by lixiviating blackash residues that had been exposed to the influence of the atmosphere. The sulphide of manganese produced was burnt, whereby sulphurous acid and manganese oxide were formed; the latter was heated with sodium nitrate, and thus transformed into a substance containing 55 per cent. of peroxide. The oxides of nitrogen which originated in the last operation were sent into the vitriol chambers.

F. KUHLMANN, of Lille, some time ago proposed

to revive the spent manganese by means of hyponitric acid. He finds that manganese nitrate heated to 390° Fahr. furnishes pure manganese peroxide. If the escaping gases, hyponitric acid, and other oxides of nitrogen, are mixed with air and passed over hydrated oxide of manganese, the latter is transformed into nitrate. The hydrated oxide of manganese is obtained from the still liquor by precipitation with lime. KUHLMANN says that he can recover in this manner 88 per cent. of the manganese originally employed in the decomposition of hydrochloric acid.

KUHLMANN'S process is, moreover, only a modification of the method described by SCHLŒSING in 1863. This method consists in heating a mixture of nitric acid and hydrochloric acid with manganese peroxide; thus are formed chlorine, manganic nitrate, and water. The nitrate breaks up on heating, as above stated, into hyponitric acid and manganese peroxide; the hyponitric acid oxidises again to hydric nitrate. The successive stages of the reaction may be expressed thus:—

(1.) $2HCl + 2HNO_3 + MnO_2 = Cl_2 + Mn(NO_3)_2 + 2H_2O$.
(2.) $Mn(NO_3)_2 = MnO_2 + N_2O_4$.
(3.) $N_2O_4 + H_2O + O = 2HNO_3$.

But the regenerative process, which has hitherto been found most practical, is the one proposed by WALTER WELDON. It rests on the fact that recently precipitated protoxide of manganese suspended in solution of chloride of calcium is, in the presence of excess of lime, easily oxidized to peroxide by means of air injected into the liquor. It is the employment of an *excess* of lime which makes WELDON'S method really available for practical purposes. The possibility of oxidizing the precipitate obtained by adding simply an equivalent of lime to the residual liquors was previously known, but all attempts to turn it to practical account had failed. WELDON discovered that whereas, when manganese protoxide by itself is treated in the wet way with air, one-half is the maximum proportion of it which can thereby be converted into peroxide, the association of a certain proportion of lime with the protoxide so treated will enable the whole of it to become converted into manganese peroxide, and this in less than one-twentieth of the time required for the peroxidation of half of it when lime is not present. It is to these facts that the brilliant success of WELDON'S method is chiefly due.

The process, as carried out on the manufacturing scale, is as follows:—The residual liquors from the still, F (see Plate I., CHLORINE), in which the reaction between hydrochloric acid and manganese took place, are run into a well, A, termed the *neutralizing well*. Here the free hydrochloric acid of the still liquor is neutralized, and its ferric and aluminic chloride decomposed, by treatment with limestone or chalk, the action of which is accelerated by energetic agitation. After this treatment the now neutral liquor consists of a mixed solution of chloride of manganese and chloride of calcium, holding in suspension small quantities of iron oxide and alumina, some little excess of chalk, and not an inconsiderable quantity of lime sulphate. The last compound owes its origin to the sulphuric acid, which is present in all hydrochloric acid produced in alkali works.

From the neutralizing well, which is usually 6 feet deep by 20 feet diameter, the liquor is pumped up, by means of the pump, G, into the tanks, B B, placed about 40 feet above ground, and called the *chloride of manganese settlers*. In these settlers the solid matters suspended in the liquor subside within from two to four hours, leaving the bulk of the faintly rose-coloured liquor bright and clear.

The clarified solution of manganese and calcium chlorides is then drawn off by means of syphons, which can be lowered or raised in the settlers to any desired level, and run into the vessel, C, called the *oxidizer*. This is usually an iron cylinder of from 8 to 12 feet in diameter, and 20 to 35 feet in depth. Two pipes go down nearly to the bottom of the oxidizer; a large one, D, for conveying a blast of air from a blowing engine, and a smaller one for the injection of steam; the steam is intended to raise the contents of the oxidizer to 130° to 140° Fahr.; but this is often unnecessary, since the liquor reaches the oxidizer in a sufficiently hot state. Immediately above the oxidizer, C, is a reservoir, H, for the reception of milk of lime. This latter has to be carefully prepared, since on its degree of fineness depends the readiness of its action in the oxidizer. It is kept continuously agitated to secure a uniform consistency, and should contain 15 to 20 lbs. of hydrate of lime in every cubic foot of cream.

The oxidizer having received a charge of clear liquor from the chloride of manganese settlers, and this liquor having been heated by steam to the proper degree, if it did not reach the oxidizer sufficiently hot, the blowing is begun, and simultaneously milk of lime is run into the oxidizer as rapidly as possible, until the filtrate from a sample ceases to give a manganese reaction with solution of bleaching powder. A further quantity of milk of lime is next added, the contents of the oxidizer then forming a thin white mud, consisting of a solution of calcic chloride holding in suspension a mixture of protoxide of manganese and free lime. The injection of air being continued, this thin white mud rapidly darkens in colour, and at length what was a thin white mud has become a thin black mud, consisting of solution of chloride of calcium holding in suspension certain compounds of MnO_2, partly with MnO, but mainly with lime, to which WELDON has given the name of "manganites."

The quantity of lime which has to be put into the oxidizer before the filtrate from a sample of its contents ceases to give a manganese reaction, varies very considerably. Recently precipitated protoxide of manganese dissolves very appreciably in neutral solution of chloride of calcium, its solution therein comporting itself with reagents exactly like solutions of manganese salts. It dissolves also in solution of oxychloride of calcium, that is to say, in solution of chloride of calcium containing dissolved lime; its solution in oxychloride of calcium *not* giving the

ordinary manganese reactions. Hence, even if all portions of the lime added to the chloride of manganese in the oxidizer were capable of acting on chloride of manganese equally readily, manganese could not cease to be so in solution as to be detectible by ordinary reagents until more than an equivalent of lime had been added — until enough had been added, that is to say, not only to decompose all the chloride of manganese, but also to form a certain quantity of oxychloride of calcium. It is never the case, however, that all portions of the lime used are capable of acting on the chloride of manganese with equal readiness. The lime used always contains a larger or smaller proportion of particles coarser than the rest, which coarser portions cannot of course act so rapidly as the finer portions; and as the decomposition of the chloride of manganese requires to be completed as quickly as possible, those portions of the lime which will not act upon it instantly are scarcely allowed time to act upon it at all. These coarser portions of the lime thus contribute very little to the decomposition of the chloride of manganese, though they afterwards dissolve completely in the hot solution of chloride of calcium, and then play their full part in the reactions which take place during the subsequent blowing. The proportion of the lime which thus does not act on the chloride of manganese varies with the source of the lime, and with the manner in which it is prepared; so that the quantity of lime which has to be added to a charge of chloride of manganese liquor in the oxidizer before the filtrate from a sample of the resulting mixture ceases to become coloured on addition of solution of bleaching powder, varies from about 1·1 to 1·45 equivalents. The further quantity of lime which is added after that point has been reached is now usually so much as to raise the total quantity to about 1·5 or 1·6 equivalents, being from one-half to six-tenths in excess of the quantity which actually takes part in the decomposition of the chloride of manganese.

It has already been stated that if only so much lime is employed as is necessary to precipitate the manganese from its solution, not more than half the precipitated protoxide of manganese can be peroxidized, and this only very slowly. To insure a greater and more rapid yield of peroxide, a larger portion of lime is required. But we have now to notice that too large a proportion of lime produces compounds which resist peroxidation. If this occurs, a fresh quantity of chloride of manganese has to be added in order to destroy those compounds. Indeed, in some works, the addition of a little chloride of manganese solution, after samples from the oxidizer cease to show an advance in oxidation, is made now in all cases.

The reason of this addition of "final liquor," as it is called, is as follows:—The compounds formed in the oxidizer are chiefly two; one consisting of an equivalent of MnO_2 combined with an equivalent of MnO, and the other of an equivalent of MnO_2 combined with an equivalent of CaO. About 20 per cent. of the MnO_2 is usually combined with MnO, and about 80 per cent. of it with CaO. The MnO and CaO thus combined with the MnO_2, are classed together under the name of "bases," for which every batch of mud is always carefully tested. Seeing that the bases neutralize hydrochloric acid without liberating any chlorine from it, the smaller their proportion to the MnO_2 of course the better. Now there are two compounds of MnO_2 with CaO, the one containing an equivalent of each constituent, and the other containing two equivalents of MnO_2 per one equivalent of CaO. Per equivalent of chlorine liberated, the former consumes three equivalents of hydrochloric acid, but the latter only two and a half. Under some circumstances, which need not here be entered into, the latter compound is formed directly; but when the operation in the oxidizer is so performed as to produce chiefly the compound containing a full equivalent of CaO per equivalent of MnO_2 in it, "final liquor" is employed, because one half of the lime in that compound is held more loosely than the other half, and can decompose chloride of manganese. The effect of final liquor, under the circumstances in question, is thus to reduce the proportion of bases to MnO_2, by converting the compound of one of MnO_2 with one of CaO into the compound of two of MnO_2 with one of CaO, and at the same time giving a further quantity of MnO, which a slight continuation of the blowing, more or less, completely peroxidizes.

The blowing lasts usually from two to four hours. The quantity of air which requires to be blown into the oxidizer, per given quantity of peroxide of manganese made, varies with a considerable number of conditions, but more especially with the depth of the charge operated upon, and with the quantity of manganese contained in a given volume of it. Within all practicable limits, increase of the depth of the column blown into is equivalent to increase of the quantity of air blown; and the more particles of protoxide are contained in a given volume of the charge, the larger is the total surface which they present for the air to act upon, and the greater is the proportion of the total oxygen injected which becomes absorbed. The proportion of the oxygen absorbed to the quantity blown in is of course greatest at the commencement of the operation, and afterwards continually diminishes, a time at length arriving, if the blowing be continued long enough, at which no more oxygen is absorbed at all; the proportion of the total quantity of oxygen absorbed to the total quantity blown in is also considerably influenced by how nearly to that point the operation be continued.

The following figures show the progress of peroxidation every half hour at two factories, one in France and one in Lancashire:—

At a Factory in France.

The charge consisted of 18,000 litres of chloride of manganese liquor; steam having been injected until the temperature had reached 60° C., and milk of lime equal to 1·6 equivalents of the chloride of manganese having been added, the blowing began at 2.50 P.M. Every half hour a sample was taken and tested for peroxide of manganese.

At 2.50 P.M. there were in the oxidizer 0·00 grms. of peroxide of manganese per litre.

At 3.20 P.M. there were in the oxidizer 10·1 grms. of peroxide of manganese per litre.

At 3.50 P.M. there were in the oxidizer 18·6 grms. of peroxide of manganese per litre.

At 4.20 P.M. there were in the oxidizer 28·9 grms. of peroxide of manganese per litre.

At 4.50 P.M. there were in the oxidizer 36·3 grms. of peroxide of manganese per litre.

At 5.10 P.M. there were in the oxidizer 40·9 grms. of peroxide of manganese per litre.

At this stage the batch was run off. The whole quantity of mud measured 51,900 litres, and contained, therefore, 51,900 × 40·9 grammes = 2122 kilogrammes of manganese peroxide, which was combined with 0·66 equivalent of bases per equivalent of peroxide.

At a Factory at St. Helens.

The charge consisted of 1243 cubic feet of chloride of manganese liquor. After it had been heated to 130° Fahr., and mixed with 1·6 equivalent of lime, the blowing began at 12.15 P.M.

A 12.15 P.M. there were in the oxidizer 0·00 lbs. of peroxide of manganese in a cubic foot of the mud.

At 1.30 P.M. there were in the oxidizer 0·83 lbs. of peroxide of manganese in a cubic foot of the mud.

At 2 P.M. there were in the oxidizer 1·12 lbs. of peroxide of manganese in a cubic foot of the mud.

At 2.30 P.M. there were in the oxidizer 1·35 lbs. of peroxide of manganese in a cubic foot of the mud.

At 3 P.M. there were in the oxidizer 1·64 lbs. of peroxide of manganese in a cubic foot of the mud.

At 3.30 P.M. there were in the oxidizer 1·97 lbs. of peroxide of manganese in a cubic foot of the mud.

At 4 P.M. there were in the oxidizer 2·24 lbs. of peroxide of manganese in a cubic foot of the mud.

At 4.30 P.M. there were in the oxidizer 2·36 lbs. of peroxide of manganese in a cubic foot of the mud.

At 4.45 there were added 124 cubic feet of chloride of manganese liquor, and blowing was continued till 5.15, when the liquor of the oxidizer contained 2·37 lbs. of peroxide per cubic foot. The batch was then run off. It measured 1751 cubic feet, containing 1751 × 2·37 = 4149 lbs. of peroxide of manganese, which was combined with 0·72 equivalent of bases.

The mechanical power expended in the injection of the air into the oxidizer averages between 4 and 5 horse-power for one hour per 100 lbs. of manganese peroxide made. The quantity of chlorine contained in a ton of bleaching powder at 37 per cent. should only require 1020 lbs. of peroxide; but, owing to the various losses of chlorine which occur in the manufacture of bleaching powder, the quantity of manganite mud actually used per ton of bleaching powder made by means of it, is ordinarily the quantity containing about 1100 lbs. of peroxide. The production of the proportionate quantity of mud may be said to require the expenditure of 40 to 45 horse-power for one hour.

The contents of the oxidizer, consisting of a solution of chloride of calcium, in which the peroxide of manganese combined with manganese protoxide and lime is suspended, are now run off from C (Plate I.), into one of a range of settling tanks, E E E, called the *mud settlers*, which are placed below the level of the oxidizer. There the mud is left at rest until it has settled as far as it will, usually until about one half of its volume has become clear. This requires about three or four hours. The clear part is then decanted by means of a swivel pipe. It is a perfectly pure solution of chloride of calcium, and is usually thrown away. The admission of this waste liquor into the rivers has, according to the opinion of the Rivers' Pollution Commission, no other ill effect than that of rendering the water a little harder.

The mud from the mud settlers, containing from 4 to 5 lbs. of manganese peroxide per cubic foot, is then ready for use in the decomposing still, F, where it is made to react upon hydrochloric acid. The still is constructed of slabs of hard siliceous sandstone, and is usually in the shape of an octagonal prism. Figs. 1 and 2, Plate II., represent respectively a section (in part), and an elevation (in part). A A, &c., are the slabs of sandstone. Each side of the still is formed of two slabs; the lower, about 7 feet high and 7 inches thick, and the upper, about 3 feet high and 6 inches thick; the width of each slab is about 4 feet. The slabs are held together by iron rods and screws (as seen in the diagrams), and where they join one another a rope of india-rubber, *a*, is inserted. The top, which consists of two stones, B B, is caulked down into a groove with red lead and oakum. The bottom, C C, which must rest on a good foundation, and which may be in two stones (as shown in the diagram), or even in four, has a thickness of 10 inches. D is an earthenware pipe widening into a funnel; into this fits a lead tube, E, from which a smaller tube, F, leading to the mud settlers, branches off. G is an earthenware tap for the admittance of the hydrochloric acid; H, the chlorine delivering tube; I, a pipe for the injection of steam, either of stone or of earthenware; J is a tap, of stoneware like G, for the elimination of the spent still liquor, which is then conveyed to the neutralizing well; and K is a manhole for admitting a workman when the still requires cleaning or repairing; at *b* is a small cock for drawing samples during the progress of the operation.

The operation in the still commences by its being charged with hydrochloric acid. (This is the reverse of the method formerly employed with native manganese, the native manganese being put into the still first, through a manhole, the still then closed, and the acid run in by a cock.) The still having been charged with acid, settled mud is run in upon the acid in a gentle stream, which can be regulated at will by a cock. Steam being gently injected at the same time, the mud dissolves almost immediately on reaching the acid, and chlorine comes off in an even current, the force and flow of which can be regulated with the utmost nicety by regulating the admission of the mud. When all the acid has been decomposed and neutralized except to the extent of from 6 to 8 ounces HCl per cubic foot, which at some works is

at the end of two hours, and at others at the end of from four to six hours, the contents of the still are run off into the well placed below it, and there the round of operations above described is recommenced. The process is thus a continuous one, and theoretically enables the initial quantity of manganese to serve over and over again an indefinite number of times.

In practice there is, however, always a loss of a small percentage of manganese. It has above been stated that the chloride of manganese liquor, after neutralisation with chalk, is left for a while at rest, before being run into the oxidizer, in order to allow sulphate of lime and other solid substances to subside. This deposit has, before being finally removed, to be washed carefully, in order to avoid throwing away with it the greater part of the manganese chloride, which it retains mechanically. This is done in tank K. Now, this deposit constitutes the only unavoidable source of loss of manganese; for though an exhaustive washing could easily be effected, the wash waters would, on account of their bulk, be of little use. A loss from about 2 to 4 per cent. (some chemical manufacturers say 8 to 10), must therefore be suffered with its removal. It is, indeed, possible to reduce this loss by careful working to less than 1 per cent., but such delicate working is only rarely attainable in extensive manufacturing operations.

Other possible sources of loss are leakage of vessels, and the running away of mud by careless workmen with the chloride of calcium solution from the mud settlers. The former of these two sources of loss ought never to exist, and the latter can be eliminated by passing the chloride of calcium solution before it is thrown away into catch-pools, in which any mud that may have come with it may be deposited.

With regard to the chief source of loss, the removal of manganese chloride with the lime sulphate, WELDON has proposed to do away with it by trying to obtain for the still operation hydrochloric acid free, at least from any appreciable quantities, of sulphuric acid. He believes this could be done by conducting the condensation of the hydrochloric acid gas coming from the salt-cake furnaces in such manner that the sulphuric acid should be retained in a special vessel intermediate between the furnaces and the present condensing apparatus. Should this plan succeed, the free hydrochloric acid of the still liquors could be neutralized by manganese mud, instead of by chalk, and this neutralization could be carried out in the still itself; dispensing with the present neutralizing wells, avoiding the chief source of loss of manganese, and utilizing that portion of the acid employed, which now leaves the stills in the free state, and is neutralized in the wells by chalk.

The chlorine produced by means of the artificial peroxide of manganese is declared to be perfectly pure, and yields a strong bleaching powder. Moreover, from 20 to 25 per cent. more bleaching powder may be produced from a given quantity of acid by means of WELDON's artificial manganese, than by means of native manganese. This larger yield of chlorine is mainly due to the artificial manganese being so easily soluble that it can very readily be caused to neutralize from 95 to 99 per cent. of the hydrochloric acid employed, which is a much larger proportion than can be arrived at with manganese ores. Further, the yield of bleaching powder is not only of high strength, but it is so with great regularity. The following table shows the average strength, for thirteen consecutive weeks, of the bleaching powder made by six large manufactories:—

Week.	Factory.					
	I.	II.	III.	IV.	V.	VI.
1st	36·9	37·8	36·7	36·3	36·6	36·6
2nd	36·1	36·8	36·7	36·2	35·1	37·4
3rd	36·5	38·0	36·6	36·1	37·2	37·9
4th	35·9	37·1	35·9	36·2	36·8	37·1
5th	35·8	36·9	36·0	36·3	36·5	37·8
6th	36·0	37·0	36·2	35·9	36·5	37·2
7th	36·5	36·0	36·3	36·6	35·8	36·8
8th	36·3	36·8	36·3	36·3	35·0	37·1
9th	36·4	36·3	36·8	35·7	35·2	37·0
10th	36·5	36·7	36·3	36·0	36·2	37·6
11th	36·8	36·8	36·2	35·9	36·0	37·2
12th	36·8	35·9	35·6	35·6	36·1	37·2
13th	36·7	35·2	35·9	36·1	36·9	37·5

When we finally consider the costs of production between the old and new processes, it may safely be said that a decided advantage has been obtained by the latter; but the price of manganese, limestone, and coals varies so much from year to year that it is difficult to state it exactly in figures—for instance, in 1873 the price of manganese was £7 10s. per ton, and in 1875 it was only £5 5s. per ton: and so far as we can ascertain on good authority, the price is tending steadily downwards.

WELDON's process, as above described, yields in an available form about one-third of the total chlorine contained in the acid employed, two-thirds going away as chloride of calcium. Finding, very shortly after the introduction of this process, that it was threatened with competition by the very beautiful process of H. DEACON, which will be described below, and which was at that time believed to be capable of yielding a larger proportion of chlorine, per unit of acid employed, than can be obtained by means of artificial peroxide of manganese regenerated by means of lime, WELDON devised, and essayed on a considerable scale, a process by which magnesia was used instead of lime for the regeneration of the manganese, and which was capable, theoretically, of yielding in the free state the whole of the chlorine contained in the acid employed (see page 486).

The methods of testing employed in connection with WELDON's process are as follows:—

I. *For MnO_2.*—The quantity of mud usually employed is 1 cubic inch. It is added to a solution of a known quantity of protosulphate of iron in hydrochloric acid. The quantity of protosulphate used must be in excess of the quantity which the MnO_2 in the cubic inch of mud can oxidize: 70 grains of the crystallized protosulphate will usually give a sufficient excess per cubic inch of the mud as run

from the oxidizer, or 150 grains per cubic inch of settled mud in the state in which it goes into the stills. If the iron salt be in excess, the mud will dissolve instantly in the cold to a clear yellow solution; if the solution be brown, enough iron salt has not been used, and the determination should be recommenced upon a fresh cubic inch of mud, using a larger quantity of protosulphate. The amount of the protosulphate left unoxidized must then be determined by addition of a standard solution of bichromate of potash, until a drop of the liquid, added to a drop of solution of ferricyanide of potassium on a white porcelain slab, ceases to give a blue colour.

It is most convenient for the bichromate solution to be of such strength that one measure of it is equal to either one grain or half a grain of $FeSO_4.10H_2O$.

The number of grains of protosulphate of iron oxidized by the MnO_2 in one cubic inch of mud, divided by 25·88, gives the pounds of MnO_2 in a cubic foot of the mud.

II. *For Bases.*—A cubic inch of the mud is added to a solution of a known quantity of oxalic acid. The quantity of oxalic used should not be less than at the rate of 75 grains of the crystallized acid per 100 grains of protosulphate oxidized by a cubic inch of the same mud. When the effervescence produced by the addition of the mud to the oxalic acid has ceased, or nearly so, the resulting mixture is gently heated, but not quite to the boiling point. If enough oxalic has been used it is then perfectly white. If it is not perfectly white, the determination must be recommenced, using more oxalic acid. The excess of oxalic acid is then determined by a standard solution of soda or potash. The proportion of bases to MnO_2 in the mud is then found by the appended table, as follows:—As the number of grains of crystallized protosulphate of iron oxidized by a given volume of the mud is to the number of grains of crystallized oxalic acid decomposed and neutralized by the same volume of the mud, so is 100 to a figure in column A of the Table against which in column B is the proportion of bases per equivalent of MnO_2 in the mud.

TABLE FOR PROPORTION OF BASES.

A	B	A	B	A	B
69·5	1·066	65·00	·868	60·50	·670
69·25	1·055	64·75	·857	60·25	·659
69·00	1·044	64·50	·846	60·00	·648
68·75	1·033	64·25	·835	59·75	·637
68·50	1·022	64·00	·824	59·50	·626
68·25	1·011	63·75	·813	59·25	·615
68·00	1·000	63·50	·802	59·00	·604
67·75	·989	63·25	·791	58·75	·593
67 50	·978	63·00	·780	58·50	·582
67·25	·967	62·75	·769	58·25	·571
67·00	·956	62·50	·758	58·00	·560
66·75	·945	62·25	·747	57·75	·549
66·50	·934	62·00	·736	57·50	·538
66·25	·923	61·75	·725	57·25	·527
66·00	·912	61·50	·714	57·00	·516
65·75	·901	61·25	·703	56·75	·505
65·50	·890	61·00	·692	56·50	·494
65·25	·879	60·75	·681	56·25	·483

Of the oxalic acid consumed by the mud, one equivalent is converted into two equivalents of carbonic anhydride (CO_2) by the second equivalent of oxygen of the MnO_2 in the mud, the MnO_2 being at the same time reduced to MnO; another equivalent combines with the MnO thus formed; and the remainder combines with the protoxides originally contained in the mud. A cubic inch of mud was added to a solution of 50 grains oxalic acid; after heating the free acid neutralized 21·75 measures of caustic soda solution, each measure of which equals 0·63 grains of acid: $50 - (0·63 \times 21·75) = 36·2975$. An inch of the same mud had previously oxidized 61·5 grains of crystallized ferrous sulphate. As 61·5 : 36·2975 :: 100 : 59. Therefore by the table this mud contains 0·604 equivalent of bases per equivalent of MnO_2. The mud used in the above example would thus decompose and neutralize, per equivalent of chlorine liberated by it, 2·604 equivalents of HCl: one equivalent being converted into water and free chlorine, and another into water and chloride of manganese, by the MnO_2 of the mud, and the remaining 0·604 equivalent being neutralized by its "bases."

III. *For Total Manganese.*—A cubic inch of the mud is dissolved in the smallest practicable quantity of hydrochloric acid. The excess of acid employed is then neutralized, or nearly so, by soda or potash. The solution is then heated to boiling, and solution of bleaching-powder gradually added to it until a very slight purple coloration is perceived. All the manganese present has then been converted into MnO_2, except an exceedingly small quantity which is in solution as permanganate, and which is so minute that it may be neglected. The product is then thrown on to a filter, and the precipitate washed with boiling water until the wash-waters are colourless, or until they cease to colour iodide of potassium paper. The precipitate is then added (the filter may be added also) to a solution of protosulphate of iron in hydrochloric acid, and the excess of protosulphate determined by potassic bichromate, just as in determining the MnO_2 in the original mud. The quantity of protosulphate used should be greater, say by nearly half, than the quantity found to be oxidized by the original mud.

The practical value of a manganite mud depends largely upon the proportion in which the MnO_2 in it is combined with bases. The smaller the proportion of bases to MnO_2 in the mud, the less acid will it consume per given quantity of chlorine liberated by it. A mud the MnO_2 in which is combined with a full equivalent of bases will consume three equivalents of hydrochloric acid; but a mud the MnO_2 in which is combined with only half an equivalent of bases will consume only two and a half equivalents of hydrochloric acid per equivalent of chlorine liberated by them respectively. Fairly good working will yield regularly a mud not containing more than 0·6 equivalent of bases.

The "strength" of the mud, in the sense of the quantity of MnO_2 contained in a given volume of it, is however quite as important, in

relation to acid consumption, as the proportion of bases in it.

Without using excess of it, and so losing MnO_2, it is extremely difficult to get the mud, whatever its strength, to neutralize the acid in the stills below the point at which there remains free from 6 to 8 ozs. of real HCl per cubic foot; and as the volume of the still-liquor, per given quantity of chlorine generated, is greater the more dilute the mud employed, it follows that the more dilute the mud which goes into the stills the greater must be the quantity of acid which comes out of them in the free state, not only having rendered no service, but having to be neutralized in the wells by limestone. A good mud should contain not less than 2·25 lbs. MnO_2 per cubic foot, as it runs out of the oxidizer, nor less than 5 lbs. per cubic foot as it runs into the stills.

The two tests which are of most importance are thus that for actual MnO_2 and that for bases. These should be made upon every batch. The test for total manganese has little practical utility, except in so far as it may be applied to manganese liquors, for purposes of stock-taking, or the like.

WELDON'S MAGNESIA PROCESS.—In the trial on a large scale chlorine was generated by the reaction upon each other of hydrochloric acid and manganite of magnesium. This operation was performed in a still, and was so managed as to yield an absolutely neutral still liquor, consisting of a mixed solution of chloride of magnesium and chloride of manganese.

This liquor was run out of the still into an iron pot, from which it was pumped up into an evaporating vessel, where it was boiled down until it had reached a temperature somewhat above 300° Fahr. Having attained that degree of concentration, it was run into a muffle furnace, in which its evaporation was continued to dryness, and the residue, piled up in heaps of thin cakes, was then gently heated with access of air. The chlorine of the two chlorides was thereby driven off, partly in the free state and partly as hydrochloric acid, manganite of magnesium being at the same time reproduced.

The chlorine obtained was partly strong, partly dilute. The proportion of the strong chlorine, generated in the still, to that of the weak chlorine, produced in the furnace, could be anything between one to one, and one to about four, at will.

When so working as to obtain strong chlorine and weak chlorine in about equal proportions, the quantity of liquor to be boiled down, per ton of total bleaching powder made, was about 105 cubic feet. As the proportion of the weak chlorine increased, the quantity of liquor to be boiled down diminished, until, when the proportion of the weak chlorine to that of the strong became as four to one, the quantity of liquor to be boiled down, per ton of total bleaching powder made, was only about 40 cubic feet.

The evaporation of the liquor down to the degree of concentration at which it should enter the furnace, was performed by the waste heat of the furnace itself.

The apparatus for this form of process was so fenced in that there was no loss of material in the solid state, as dust or otherwise; and a floor impervious to liquor, and sloping from all parts towards an iron pot into which any liquid spilt upon it cannot but run, precluded all risk of loss of material in the state of solution. A little fresh magnesia was required to be supplied from time to time, owing to the sulphuric acid in the hydrochloric acid forming sulphate of magnesium, which at suitable intervals had to be dissolved out from the furnace product; but the quantity of magnesia thus converted into sulphate was but slight, and the value of the sulphate was greater than the cost of the magnesia required to replace it.

The magnesia was purchased as "Greek stone," which is a very pure magnesite, or native carbonate of magnesium, and the manganite of magnesium was produced, in the first instance, by neutralizing with Greek stone an acid solution of chloride of manganese, and then treating the resulting mixed solution of chloride of manganese and chloride of magnesium as above described.

The chlorine, which left the furnace as acid, and which was collected as such in a condenser, was returned to the still, and thus the whole of the chlorine contained in the acid supplied to this process was obtained in the free state, partly strong and partly dilute. The strong portion was applied to the manufacture of bleaching powder in the ordinary chambers, the dilute portion to the production of bleaching liquor and potassic chlorate.

The magnesia process yielded therefore the *whole* of the chlorine contained in the acid employed, except to the extent of some loss from merely mechanical sources; there was absolutely no loss from a chemical source.

Plant for this process was erected in three factories, and very considerable quantities of chlorine were made by it; but in each case, when the apparatus fell out of repair, it was replaced by apparatus for the lime process.

DEACON'S CHLORINE PROCESS proposes to do away with the use of the manganese altogether, and to bring about the decomposition of the acid in a more direct manner.

It was known that cupric chloride, when strongly heated, splits up into cuprous chloride and free chlorine—

$$2CuCl_2 = Cu_2Cl_2 + Cl_2.$$

LAURENS has proposed to utilize this reaction for the production of chlorine on a large scale. It was further known that the cuprous chloride is transformed in a current of air into cupric oxychloride. This peculiarity led also to proposals for manufacturing chlorine, but it was never tried on a large scale.

When a mixture of gaseous hydrochloric acid and atmospheric air is passed over heated bricks, or other porous substances, water and free chlorine is obtained. OXLAND had attempted to make use of this reaction for obtaining chlorine on a manufacturing scale, but without success; very likely because the temperature at which the hydrochloric acid is

decomposed by oxygen is also that at which the newly formed water is decomposed by the chlorine liberated in the first part of the operation.

DEACON'S process is a combination of the two preceding ones, though H. DEACON seems to have reached his conclusions by wholly different channels. He found that the decomposition of a mixture of hydrochloric acid gas and atmospheric air takes place at a considerably lower temperature when the mixture is passed over heated copper, manganese, or lead salts (lead sulphate excepted), instead of bare bricks. Copper sulphate proved most efficient; porous bricks saturated with the solution of this salt and heated to a temperature between 700° Fahr. and 750° Fahr., burn the whole of the hydrochloric acid passed over them, together with excess of atmospheric air, to water and chlorine. An increase of temperature above 750° Fahr. proves injurious, inasmuch as at about 800° Fahr. cupric chloride is beginning to volatilize. The best temperature appears to be 625° Fahr. To increase the power of resistance to decomposition, as well as the efficacy of the copper sulphate, the addition of some glauber salt to the saturating solution has been proposed by Mr. DEACON.

The hydrochloric acid required in the process is got either directly from a soda furnace, or evolved from the aqueous solution. The latter way is the preferable one in small works, since it allows the keeping up of the regularity of the current, whilst the evolution of the hydrochloric acid in the soda furnace is in the beginning rather violent, and towards the end sluggish; to remedy this drawback in larger works, several furnaces are in succession employed for the production of the acid, so that if the current from one furnace begins to slacken, a second may be put into operation, &c. The hydrochloric acid gas, by whichever way obtained, is immediately mixed with a quantity of air, which contains more oxygen than required for liberating all the chlorine from the hydrochloric acid evolved, and passed through heated U-shaped cast-iron tubes, which impart to the mixture the necessary temperature. The composition of the gaseous mixture can always be ascertained by drawing (by means of a small air-pump) a measured volume of it, and passing it through a standardized solution of soda coloured by some litmus.

Fig. 1 (CHLORINE, Plate III.) represents a sectional elevation of one form of DEACON'S apparatus taken along the line 1—2, in Fig. 2; and Fig. 2 is a corresponding sectional plan taken along the line 3—4, in Fig. 1.

A, B, C, D, E, F, G, H, and I are a series of towers, constructed of iron or other material, through which the heated gases pass. The first or lowest portion of the first tower, or the whole of the first and second towers, are filled with the impregnated materials, arranged with vertical spaces (ordinary agricultural drain pipes of small bore are used for this purpose).

The other towers are filled with the impregnated materials in small pieces, spherical, flat, or mere shreds of burnt clay; the object being to obtain the largest possible surface over which to pass the gases in the smallest bulk, consistent with sufficient passage-room, without the necessity of an inconveniently great draught or propelling pressure. P P P are the vacant chambers or spaces into which the dust-like substance from the interstices in the towers above descends through the open grating or perforated plate, Q, and are therein collected and removed as required.

Preceding the towers is the apparatus, O, which DEACON terms the "heat regulator;" it is constructed of the same materials as the towers, and is filled with ordinary bricks, set open or reticulated. Its office is to prevent sudden changes in the temperature of the gases reaching the towers. The contents of this "heat regulator" either receive or impart heat as the gases increase or decrease in temperature, and to this extent "regulate" the temperature of the gases passing through it. This regulator is apart from the rest of the apparatus, to avoid transmission of heat by conduction.

It is easy by means of this apparatus to maintain a current of gases for twenty-four hours without skilled attendance, at temperatures varying not more than 60° Fahr. The temperature here, as in all other parts of the apparatus, is ascertained by metallic pyrometers. According to latest informations, however, there seems to be no absolute necessity for the use of this regulator, and Mr. DEACON thinks that the efficiency of his decomposing towers is not at all impaired by doing away with the regulating tower.

The towers and heat regulator may be surrounded with brickwork, in which are left the flues, L L, communicating with fireplaces, N N. These fires and flues are not necessarily to be used as sources of heat, but surround the towers with a heated envelop, so that the loss of heat from the towers themselves may be regulated as desired or prevented altogether. The temperatures of the various parts are ascertained by pyrometers, or in any convenient manner.

The heated gas enters the apparatus by the pipe K and leaves by M, following the course of the arrows through the nine decomposing towers, A, B, C, D, E, F, G, H, I. The dust which falls through the gratings, Q, Q, Q, into the receptacles, P, P, P, is iron chloride (or iron oxide, arising from the decomposition of the chloride), and comes from the U-shaped iron tubes in which the gases undergo the preliminary heating, and also from the iron pans in which the salt is treated with the sulphuric acid. The former source of iron chloride may be done away with by substituting for the heating in iron tubes, COWPER'S method of heating hot-blast for iron furnaces, viz., to heat a mass of brickwork, then cut off the fire to heat another mass, and pass the gaseous mixture of hydrochloric acid and atmospheric air through the heated mass; by the time that it is cooled the second mass will be heated, when the current of gas will be reversed, and so on. H. DEACON thinks, however, that by increasing the diameter of the iron pipes, and by carefully moderating the heating, the volatilization of the iron chloride in this place may be avoided. As to the second source of the chlorides of iron, the soda pans, the employment of leaden instead of iron pans, would to a great extent prevent the introduction of iron into the decomposing towers.

The gases are propelled by the aid of a chimney draft, and the speed of the current is measured by an anemometer devised by Dr. HURTER.

Mr. DEACON has of late proposed to unite all the nine towers into one space, *i.e.*, to do away with the walls of partition, and also to substitute ordinary brick-pieces for the drain pipes. Indeed, this plan has been tried already in KUHNHEIM'S factory, at Berlin, and the working has gone on for several months without interruption.

Without entering at length into the theory regarding the action of the copper salt, we may give the conclusions which DEACON draws from the experiments which he has made in conjunction with Dr. HURTER:—

(1.) That with the same mixture of gases, and at the same temperature, the amount of hydrochloric acid decomposed by the aid of a molecule of the copper salt in a given time, depends upon the number of times the molecules of mixed gases are passed through the sphere of action of the copper salt. Conversely, that the activity of a molecule of copper salt depends upon the speed with which fresh matter is presented to, and the products are removed from it.

(2.) That in long parallel tubes of the same diameter, the number of opportunities of action in the same time is nearly the same at all velocities of the current of gas.

(3.) That in long parallel tubes of different diameters, the number of opportunities of action of each molecule of copper salt is the same when the velocities of the currents of gas are in inverse proportion to the squares of the tubes' diameters.

(4.) That in porous matters the opportunities of action increase with increased velocities of the current of gas in nearly direct proportion.

(5.) That, other conditions remaining the same, the percentage of hydrochloric acid decomposed in any given time varies with the square root of the proportionate volume of oxygen to hydrochloric acid. Conversely of course, the percentage of oxygen used varies with the square root of the proportionate volume of hydrochloric acid to oxygen.

(6.) That the cupric chloride formed bears no definite proportion to the quantity of chlorine produced.

(7.) That as the sphere of action includes molecules not in contact with the copper salt, therefore hydrochloric acid must be decomposed under circumstances where the union of either element with the copper salt is impossible, *i.e.*, that the decomposition must in part, if not entirely, be caused by the resultant of the forces engaged, and therefore direct from $2HCl + O$ to $H_2O + 2Cl$.

The gaseous mixture of hydrochloric acid and air consists, on leaving the decomposing apparatus at M, of chlorine, water, nitrogen, unconsumed oxygen, and undecomposed hydrochloric acid. The colour of the resulting gases gives a good indication of the success of the decomposition; and the proportion of hydrochloric acid is easily ascertained when desired, by a finger-pump, drawing known quantities at each stroke through a normal alkaline solution coloured with litmus. The greater the number of strokes required before the blue colour is changed to red, the more air and less acid gas is present, and *vice versa*. The hydrochloric acid is separated from the mixture by conducting it, after previous cooling, through water; the water of the mixture is fixed by sulphuric acid, which runs down over coke in a tower, and through which tower the mixed gases are passed. The gases thus purified are ready for the making of bleaching powder. Of course, if an aqueous liquid is to be saturated with chlorine, as is the case in the preparation of chlorate of potash, there is no need for drying the gases.

An objection made to this process was that volatilization of the copper salt would soon diminish the decomposing efficiency of the bricks, and finally stop the operation altogether. To this objection Mr. DEACON replied by stating that at the temperature mentioned above, at which the decomposition of the hydrochloric acid takes place, no appreciable quantity of copper chloride volatilizes. Recently he has devised a remedy for even this small loss. Steam is passed over the bricks, after the furnace has been cooled down to about 220° Fahr.; the steam dissolves the copper sulphate in the interior of the porous brick pieces, and this solution, by flowing over the outer surfaces of the clay pieces, deposits there a new layer of copper sulphate.

The next point that was urged against the practicability of DEACON'S process was the great bulk of the gases evolved, and the necessity of having to construct enormously large chambers for the preparation of bleaching powder.

To counteract this disadvantage, H. DEACON passes the gas through a series of chambers, in which the first contains nearly finished bleaching powder, the next less saturated lime, and so on, until the last is filled with lime as usually slaked for the manufacture of bleaching powder. In this way the gas volume richest in chlorine comes in contact with lime nearly saturated with chlorine, whilst the gas which has been deprived of almost all its chlorine passes over slaked lime that has not yet been in contact with any chlorine.

That the bleaching powder made from chlorine obtained according to DEACON'S method is of great strength, and that it is so with some regularity, may be seen from the following table of chamber tests for fourteen consecutive working days:—

		STRENGTH.			STRENGTH.
July	14	36·0	July	22	34·3
"	15	34·8	"	"	36·5
"	"	36·1	"	24	36·8
"	17	36·4	"	"	37·5
"	"	36·0	"	25	36·1
"	18	37·2	"	"	36·7
"	"	37·9	"	"	36·8
"	19	37·2	"	26	36·2
"	"	37·0	"	"	36·9
"	20	37·9	"	27	36·9
"	"	36·7	"	"	35·5
"	21	36·0	"	28	37·2
"	"	35·3	"	"	37·0
"	"	37·7	"	29	36·75

Another proposition of Mr. DEACON for the production of chlorine was to pass a mixture of air (or oxygen) and vapour of anhydrous sulphuric acid (SO_3) over heated sodium chloride. This proposition has been modified and generalized by DE LALANDE and PRUD'HOMME. They find that when a mixture of silica and the chloride of an alkali metal, alkaline-earth metal, or earth metal, is heated to redness, and subjected to the action of a current of air or oxygen, chlorine is evolved, and the chloride is converted into a silicate—

$$SiO_2 + 2NaCl + O = Na_2SiO_3 + Cl_2.$$

On treating the resulting silicate with a mixture of hydrochloric acid and oxygen, the silicate is decomposed, and the original chloride reproduced—

$$Na_2SiO_3 + 2HCl = SiO_2 + 2NaCl + H_2O.$$

In this manner a continuous evolution of chlorine can be secured.

The water formed in the second reaction leads to two secondary reactions:—

(*a*) The water is decomposed by the chlorine—

$$H_2O + 2Cl = 2HCl + O;$$

(*b*) The chloride is decomposed by the water—

$$2NaCl + H_2O = Na_2O + 2HCl.$$

The silica may be replaced by boric, stannic, and phosphoric acids, alumina, pumice stone, and pieces of brick, with quite as good results.

The temperature required in these decompositions is somewhat higher than in DEACON'S process.

A modification of DEACON'S copper salt method has been patented by W. HENDERSON. According to this, a mixture of hydrochloric acid gas and air are passed over bricks made of iron oxide and a little clay, heated to about 400° Fahr.

The importance of the bleaching industry gave occasion to a great many other propositions for the production of chlorine; but since most of them are as yet far from practical realisation, we must pass them over.

The following information as to the prices of bleaching powder has been supplied by Mr. R. C. CLAPHAM, and may be interesting to manufacturers:—

In 1805	£120	0	0	per ton.
" 1810,	84	0	0	"
" 1815,	80	0	0	"
" 1820,	47	0	0	"
" 1825,	27	0	0	"
" 1830,	23	0	0	"
" 1832,	21	0	0	"
" 1835,	23	10	0	"
" 1840,	21	0	0	"
" 1846,	18	10	0	"
" 1850,	13	15	0	"
" 1855,	10	15	0	"
" 1857,	13	10	0	"
" 1860,	11	0	0	"
" 1868,	10	12	0	"

Chlorometry.—The value of bleaching powder depends upon the quantity of chlorine which may be liberated from it under the influence of an acid, and hence the estimation of this quantity is of importance to the bleacher.

Chlorine, whether in the free state, or combined with weak alkalies or caustic lime, having the property of destroying colouring matter of an organic nature, this reaction was, from the first, resorted to as a means of determining the commercial value of its compounds as bleaching agents. One part of best commercial indigo blue is dissolved in nine parts of concentrated sulphuric acid, then diluted to any required point, and the quantity of chlorine required to discharge the colour ascertained by a known weight of chlorate of potash, decomposed by hydrochloric acid—the chlorine thus evolved absorbed by potash, as in the case of manganese, and this solution added from a graduated test glass to a certain amount of the coloured liquor. Sometimes this species of testing is performed in the following manner:—The sample of bleaching powder is weighed and dissolved in a known volume of water, then the standard measure of strongly acidulated solution of indigo poured into it till the colour ceases to be destroyed. Unless the operator mixes the tests in a stoppered bottle, a loss of chlorine will result from the action of the strong acid solution upon the lime compound. As a check upon the first determination, a second estimation should be made, in which case the whole of the solution required in the preceding instance should be measured off in a tube graduated from below upwards, and added to within one or two divisions to the bleaching liquor at once, and the whole well agitated. After the greater part of the chlorine has been thus combined, the traces still remaining may be easily absorbed by the residuary portion of the indigo test solution. It is more convenient to add the bleaching solution to the indigo until it loses the colour.

But the indigo test is very unsafe. In the first place, the indigo solution decomposes spontaneously by standing, even when kept in well stoppered bottles and in the dark. Next, it is very difficult to ascertain when the reaction is complete, for the yellow colour, resulting from the decomposition of the indigo mixing with the original blue colour of the solution, produces a green tint, which interferes with the correctness of the observation.

GAY-LUSSAC was the earliest to devise an accurate method. It is based on the property of a solution of arsenious acid, As_2O_3, in hydrochloric acid to become oxidized to arsenic acid, As_2O_5, in the presence of chlorine and water. The reaction may be represented by the equation—

$$As_2O_3 + 2H_2O + 4Cl = As_2O_5 + 4HCl.$$

The reaction is very rapid. If organic substances, capable of being decolorised by the action of chlorine, are present while it is taking place, the colour is not destroyed so long as any portion of arsenious acid remains unconverted into arsenic acid; but as soon as the last portion of the arsenious acid has been oxidized, the liquor is instantly decolorised, and this reaction at once indicates the end of the experiment.

Taking the equivalent number of arsenious acid = 198, that of chlorine = 35·5, it is evident that

198 grains of arsenious acid will correspond to $4 \times 35 \cdot 5 = 142$ grains of chlorine; or, which is the same, 139·4366 grains of arsenious acid will correspond to 100 grains of chlorine.

Take, therefore, a certain quantity of the arsenious acid of commerce, reduce it to powder, and dissolve it in hot diluted hydrochloric acid; allow it to crystallize therefrom, wash the crystalline powder with cold water, dry it well, reduce to fine powder, and of this put 139·44 grains into a flask, add thereto about 3 ozs. of pure hydrochloric acid, one that is absolutely free from sulphurous and nitric acid, and which has been, before addition, diluted with three or four times its bulk of water, and keep the whole boiling until all the arsenious acid has dissolved. Pour now the solution into a glass cylinder graduated into 10,000 grains-measures, rinse the flask with water, pour the rinsings into the cylinder, and fill it up with more water to the mark 10,000. It is clear that 1000 measures of this solution contain 13·944 grains of arsenious acid, which require to their conversion into arsenic acid 10 grains of chlorine.

A sample of 100 grains of the bleaching powder to be examined is then weighed, triturated with some water in a mortar, and to the turbid milky solution so much water is added that 10 grain-measures of the solution—representing one degree —shall contain 0·5 grains of bleaching powder.

Pour now 1000 grains of the arsenious acid test liquor into a large beaker, add to it a few drops of sulphate of indigo solution in order to colour it distinctly blue, shake the glass so as to give a circular motion to the liquid, and while it is whirling round pour gradually into it the chloride of lime liquor, watching attentively the moment when the blue tinge of the standard acid is destroyed.

The quantity of available chlorine in the sample is then determined in the following manner:—

Let us suppose that it required 90° of the bleaching powder liquor to destroy the blue colour of the 1000 grain-measures of the acid test liquor, then it is evident that these 90° contained the 10 grains of chlorine necessary for the complete oxidation of the 13·944 grains of arsenious acid in the 1000 parts of test liquor; and since each degree contains 0·5 grains of bleaching powder, the 90° must have 45 grains, and consequently the 10 grains of chlorine were in these 45 grains of bleaching powder. A simple proportion leads now to the percentage,—

$$45 : 10 = 100 : x$$

$$x = \frac{10 \times 100}{45} = 22\tfrac{2}{9}$$ per cent. of available chlorine was in the sample investigated.

It is necessary to pour the bleaching powder liquor into the acid test liquor, because otherwise the hydrochloric acid of the acid test liquor would disengage suddenly more chlorine than the arsenious acid could absorb; some chlorine would escape, and thus render the result incorrect.

RUNGE, and after him GRAHAM, have made ferrous sulphate, $FeSO_4$, the basis for the standard solution. This salt is transformed by chlorine, in the presence of free sulphuric acid, into the ferric sulphate, thus:—

$$FeSO_4 + H_2SO_4 + 2Cl = Fe_2(SO_4)_3 + 2HCl.$$

To obtain the iron salt in a pure state, so much fine pianoforte wire is dissolved in not too dilute sulphuric acid as will nearly neutralize it; the liquor is then filtered and set aside to crystallize, care being taken to keep it slightly acid, and a few fragments of the wire suspended in it, to prevent oxidation by the hydrogen evolved. In this case the crystals are well-defined oblique rhombic prisms of moderate size; but if it be desired to obtain them of less size, the slightly acid concentrated hot lye is filtered into strong alcohol, when the salt precipitates in a finely clear pulverulent state. When the crystals are separated from either of these menstrua, and dried between folds of blotting paper, they have the composition expressed by the formula, $FeSO_4 + 7H_2O$, the equivalent of which is 276. Now it has been shown that two equivalents of chlorine, *i.e.*, 71 parts by weight, will oxidize one equivalent, *i.e.*, 278 parts, of the crystallized protosalt; and, based upon these numerical relations, it is easy to prepare standard solutions and then to make the necessary calculations.

The indicator in this case is potassic ferricyanide, which salt gives a blue precipitate with any protosalt of iron. The progress of the oxidation of the iron protosulphate is, therefore, measured by dipping the end of a stirring rod into the standard liquor, after it had been well shaken on the addition of the sample liquor, and bringing the rod end in contact with drops of a concentrated solution of potassic ferricyanide, dotted on a white porcelain slab; when the colouring produced appears greenish yellow, the oxidation of the iron protosulphate into sulphate has become complete.

PENOT has modified GAY-LUSSAC's test by bringing about the oxidation of the arsenious acid in an alkaline, instead of in an acid solution, and he employs a test-paper moistened with starch paste, containing iodide of potassium, to show when the reaction is completed. A solution of 139·44 grains of purest arsenious acid in a few ounces of water is prepared, and about 700 grains pure carbonate of soda (specially free from every trace of sulphide or hyposulphite) are added to it. The mixture is boiled until the solution has become clear, filled into a standard cylinder, which, after the cooling of its contents, is filled up with water to 10,000 grain-measures.

The starch test is prepared by boiling 3 parts of starch with 500 of water, and afterwards adding 1 part of iodide of potassium. Slips of filtering paper are dipped into the mixture and used whilst still damp, in which state they are far more sensitive than when dried.

The bleaching-powder solution is prepared as in GAY-LUSSAC's method. Of this solution 1000 grains are, immediately after thorough shaking up, measured out with a pipette, and transferred into a beaker; a graduated burette having been filled up to the proper height with the soda arsenite liquor, its contents are

gradually run into the bleaching powder solution, till a drop of this taken out with a glass rod ceases to produce any coloration upon a piece of the starch-test paper. The operation is then completed.

If the burette contains 1000 grains divided into 100 parts, 1 part corresponds to 1 per cent. of chlorine, as can easily be seen from the equation and the calculations already given.

BUNSEN recommends to add the iodide of potassium to the bleaching-powder liquor, to acidulate the mixture with hydrochloric acid, and to run the soda arsenite solution into it till only a yellow tint shows itself. A little starch paste is now added, and the arsenite solution cautiously introduced drop by drop till the blue colour just disappears. Of course, the solutions are all standardized.

Since the starch paste is apt soon to decompose, MOHR advises to add to it a little chloride of zinc.

G. LUNGE states that the same piece of moist test-paper may serve for any length of time, since the spots produced in testing soon disappear (usually after about twenty-four hours), on leaving the paper exposed to the influence of the air, only providing against its becoming covered with dust.

G. E. DAVIES proposes to use glycerin as solvent for the arsenious acid. His standard solution is:— 13·95 grains of arsenious acid in 40 cc. of glycerin, and filled up to 1 litre. Every 10 cc. corresponds to 0·1 grain of chlorine. Indigo sulphate solution is used as indicator, and the bleaching liquor is run into the glycerin solution, until the blue colour of the latter is changed to a brownish yellow.

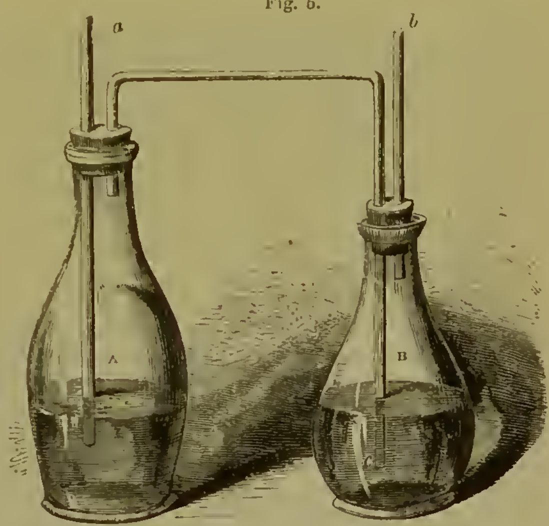
J. SMYTH, jun., thinks the use of the milky solution of bleaching powder in chlorometry unsatisfactory, and recommends, for the purpose of obtaining a clear solution, the addition of 20 grammes of soda-crystals ($Na_2CO_3 + 10H_2O$) to 10 grammes of bleaching powder, and after filtering out the precipitated carbonate of lime (which is known to be washed when it no longer discharges the colour of dilute indigo sulphate), making up the filtrate with water to 1 litre of fluid.

MANGANESE.—This mineral occurs in combination with baryta, silica, iron, potash, lime, magnesia, cobalt, &c. It is found in Germany, Spain, France, Belgium, and Holland, and smaller quantities are raised in England, Piedmont, America, and Austro-Hungary. The difference in the composition of the various ores is very great, but the samples met with in commerce are usually mixtures of different ores. The following is, after G. TISSANDIER, the composition of some of the commercial manganese ores:—

	From Germany.	From Spain.	From Mexico.	From Chili.
Water,..............	1·14	2·20	1·00	3·22
Silica,..............	14·05	9·25	5·85	4·27
Manganese peroxide,..	71·21	74·10	80·24	61·50
Iron oxide,...........	10·39	14·21	6·18	30·41
Alumina,.............	1·21	0·12	1·80	0 60
Calcium carbonate,....	2·00	0 12	4·93	trace
	100·00	100 00	100·00	100·00

The best and simplest method for determining the amount of peroxide in a sample of manganese ore is that of FRESENIUS and WILL. It consists in reducing it to very fine powder, weighing out a certain portion, and introducing it into the flask, A, in the annexed Fig. 5; two and a half times the weight of the manganese are then taken of neutral oxalate of potash, and about two ounces of water are poured into the same bottle, after which the flask, B, is filled to about two-thirds of its capacity with strong sulphuric acid; both flasks are next closed by the doubly perforated corks, into which the tubes are inserted, as represented in the figure. The apparatus is now wiped dry, and placed upon the pan of the balance, and the weight noted; the tube, a, is then closed by a piece of wax, and suction is applied at the tube, b; by this means a partial rarefaction of the air in the flasks is produced, and on withdrawing the mouth from b, the influx of air forces a portion of the acid over through c into A, which, coming in contact with the manganese and potash salt, evolves

Fig. 5.



carbonic acid by the oxidation of the oxalic acid in the oxalate.

This gas escapes through the tube, c, and the sulphuric acid in the flask, B, and finally by the short open tube into the air. When the generation of the gas takes place but feebly, a fresh quantity of sulphuric acid is forced over, and the operation thus continues till all the black mineral is decomposed, and no more carbonic acid is generated, even in the presence of an excess of sulphuric acid. The wax stopper is then removed from the tube, a, and suction applied at b, till all the carbonic acid in the flask, A, is carried off. A careful wiping of the flasks is now necessary, after which they are weighed. The results of the former and the latter weighings differ directly according to the weight of carbonic acid which has been formed from the oxalic acid.

From this it is clear that every equivalent of peroxide of manganese operated upon in the way described, gives rise to two equivalents of carbonic acid; and as the atomic weight of these is the double

of 44—this being the equivalent of the dry and pure gas—or 88, which is almost the equivalent weight of the peroxide, which in reality is 87, it is evident that the weight of the carbonic acid ascertained is the same as that of the pure peroxide required to produce it. In testing manganese in this way, it is necessary that the tubes and corks should fit air-tight, and that the oxalate should be neutral and free from carbonate. The carbonic acid gas, as it passes through the sulphuric acid, is divested of any moisture which might have accompanied it from the flask, A. Sometimes oxalic acid is used instead of oxalate of potash, but as it gives off carbonic acid immediately on coming in contact with the manganese and water, more or less of which escapes before the apparatus is weighed, the results are not so accurate as when the oxalate of potash is used.

The sample of manganese must, previous to this treatment, be digested with some dilute nitric acid, in order to expel the carbonic acid of the lime and magnesia carbonates, which may be present in the ore.

A modification of this method has been proposed by MOHR. It is executed in the following manner: —Three grammes of the finely-powdered and dried manganese ore are mixed in a small glass flask with a little water, and enough sulphuric acid to render the whole mass perfectly fluid. This flask and a porcelain capsule containing about nine grammes of crystallized oxalic acid, are now placed in one scale of the balance, and brought into equilibrium by a basin of sand or small shot. The oxalic acid is now thrown into the flask, where it immediately begins to reduce the binoxide of manganese under evolution of carbonic acid. To accelerate this decomposition, it is good to give the flask a circular horizontal motion, until the evolution of the carbonic acid has ceased, and the mass from black, which it was, has become light-coloured. The empty porcelain capsule and the glass flask are now again placed on the balance, and so much weight placed with the capsule as to restore the equilibrium. The weight required to effect this is equal to the weight of the peroxide of manganese in the ore, because one equivalent of peroxide = 87, when treated with oxalic and sulphuric acids, cause the evolution of two equivalents of carbonic acid = 88; therefore, practically, one part by weight of peroxide of manganese is indicated by one part of carbonic acid.

Now, as 3 grammes of ore have been employed for the above experiment, it follows that the amount of carbonic acid lost, divided by three, indicates the amount of peroxide of manganese in one gramme of the ore; and by multiplying the latter number with 100, the percentage of the peroxide is obtained. The error produced by the loss of water in this method does not signify for most practical purposes, but may be remedied by closing the flask with a cork in which a glass tube filled with dry chloride of calcium is fastened. In this case, however, the carbonic acid contained in the flask when the experiment is finished must be removed by suction.

In estimating the value of a sample of manganese ore for the production of chlorine, the quantity of iron contained in the ore must not be left out of sight, since it will withdraw a certain proportion of hydrochloric acid from the production of free chlorine.

CHLOROFORM.—See CHLORAL AND CHLOROFORM.

CITRATE OF MAGNESIA.—See MAGNESIA, GRANULAR EFFERVESCENT CITRATE OF.

CITRIC ACID.—*Acide citrique*, French; *Citronsäure*, German; *Acidum citricum*, Latin ($C_6H_8O_7$).—The first account which we have of any attempt to purify lemon juice is that of Georgius, a Swedish chemist, who in 1774 proposed to concentrate it by exposure to a freezing temperature. The frozen portions, consisting of ice and mucilage, were then removed, and the operation repeated until the liquid was reduced to about one-eighth of its original bulk. In 1784 SCHEELE succeeded in obtaining citric acid in a crystalline state, and proved that it was distinct from tartaric acid. Citric acid exists ready formed in the acid juice of many fruits, as the lemon, orange, lime, cranberry, and whortleberry; also in the currant, gooseberry, cherry, &c., mixed however with a considerable proportion of malic acid.

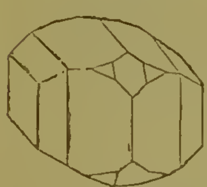
Citric acid is especially abundant in lemon and lime juice, from which it may be procured in the following manner:—The juice is sometimes submitted to an incipient fermentation, with the view of separating the mucilage, which is deposited, and the supernatant clear liquor is then poured off for use, or the juice is heated, and clarified by white of egg; it is then saturated at a temperature near its boiling point with very finely-powdered carbonate of lime, which is added in small portions as long as effervescence takes place, 16 parts of the juice requiring about 1 part of the earthy carbonate. It has been noticed, that owing to the formation of an acid salt of lime, the elimination of carbonic acid ceases before the whole of the citric acid is precipitated: in order to effect which, small quantities of hydrate of lime may be added until the liquid no longer exhibits an acid reaction; it is then permitted to cool, and the citrate of lime collected upon a strainer, and well aspersed with warm water, until the percolating liquor runs off clear and colourless. The contents of the strainer are then decomposed by placing them in a hot mixture of 1 part of strong sulphuric acid diluted with 6 parts of water. Care must be taken in this part of the process to mix the lime salt intimately with the acid by constantly stirring the liquid. When the mixing is completed, the whole is left at rest for several hours until the decomposition of the citrate is terminated; the clear solution is then decanted from the deposited sulphate of lime, which is washed with a little cold water. The citric liquor may now be evaporated until it acquires the spec. grav. 1·13, after which steam-heat or a water-bath must be used, so as gradually to expel aqueous vapour. As soon as the liquid becomes sirupy, or a pellicle forms on its surface, the heat must be withdrawn, to prevent decomposition. In about four days the mother liquor is poured off the crop of crystals, and evaporated with the same precautions as before, and this

is repeated until *clean* crystals are no longer obtained; the remaining liquor is then diluted, and submitted to the same treatment as the original lemon juice. Several solutions and recrystallizations are required to obtain the citric acid pure; in fact, it is occasionally necessary to filter it through animal charcoal.

Currants or gooseberries may be employed as a source of this acid. they are to be bruised, the expressed juice fermented, and then distilled to obtain the alcohol; the residue is saturated with chalk, and the citrate of lime decomposed by sulphuric acid—100 lbs. of the fruit yield 10 lbs. of spirit and 1 lb. of citric acid.

This acid occurs in commerce under the form of regular transparent colourless prisms, belonging to the right prismatic or trimetric system (Fig. 1). Their composition may be represented by the formula, $C_6H_8O_7 + H_2O$, but a boiling concentrated solution of the acid, as it cools, deposits crystals of a different form, which, according to some chemists, have the composition $2C_6H_8O_7 + H_2O$. Citric acid has an intensely acid but agreeable taste, and dissolves in ·75 of its weight of water at 15° C., and in half its weight at 100° C. The crystals also dissolve in alcohol, but are insoluble in ether.

Fig. 1.



Crystallized citric acid effloresces in warm dry air, and at 100° loses all its water of crystallization, leaving the dry acid of the composition, $C_6H_8O_7$.

6 atoms of Carbon, ...	72	..	37·50
8 atoms of Hydrogen, ...	8	..	4·17
7 atoms of Oxygen, ...	112	..	58·33
	192	..	100.00

Citric acid is a tribasic acid, and its constitution may be represented as $(C_3H_4)\begin{cases}OH\\(COOH)_3,\end{cases}$

or, $\begin{cases}CH_2.COOH\\CH.COOH\\CH_2.COOH,\end{cases}$ in which the hydrogen of one or more of the COOH groups may be replaced by a metal such as potassium, giving rise to three series of salts, $C_6H_5O_7KH_2$, $C_6H_5O_7K_2H$, $C_6H_5O_7K_3$. A great number of these have been examined and described, but none of them, except the neutral calcium salt, $(C_6H_5O_7)_2Ca_3 + 4H_2O$, possesses any special interest for the technical chemist.

If a few drops of a solution of citric acid be added to lime water, it produces no apparent effect until the mixture is boiled, when a white precipitate of calcium citrate is produced, which is soluble in acids without effervescence.

DECOMPOSITIONS.—The action of heat on citric acid has occupied the attention of many chemists, among whom may be mentioned LASSAIGNE, DUMAS, BERZELIUS, and ROBIQUET, the results of whose experiments were apparently contradictory and irreconcilable. The researches of CRASSO, however, cleared up and reconciled the inconsistencies of his predecessors. According to this chemist, crystallized citric acid, when exposed to heat, exhibits four stages of decomposition.

When heated in a retort, it first melts and boils, giving off its water of crystallization. At a higher temperature, about 175° C., decomposition takes place; acetone distills over, accompanied by a copious evolution of carbonic oxide and carbonic anhydride, and at this stage *aconitic acid* remains in the retort. On continuing to apply heat, the aconitic acid is decomposed, carbonic anhydride being disengaged, whilst *itaconic acid* condenses in oily striæ on the neck of the retort. When cold, this oily liquid solidifies to a mass of crystals, which, on being repeatedly distilled, lose water and become converted into *citraconic anhydride*, an oily substance which no longer solidifies on cooling. The changes which citric acid successively undergoes in these operations may be represented by the following equations:—

$$\underset{\text{Crystallized Citric Acid.}}{C_6H_8O_7 + H_2O} = \underset{\text{Dry Citric Acid.}}{C_6H_8O_7} + H_2O.$$

$$\underset{\text{Citric Acid.}}{C_6H_8O_7} = \underset{\text{Aconitic Acid.}}{C_6H_6O_6} + H_2O.$$

$$\underset{\text{Aconitic Acid.}}{C_6H_6O_6} = \underset{\text{Itaconic Acid.}}{C_5H_6O_4} + CO_2.$$

$$\underset{\text{Itaconic Acid.}}{C_5H_6O_4} = \underset{\text{Citraconic Anhydride.}}{C_5H_4O_3} + H_2O.$$

The acetone and carbonic oxide observed in the second stage of the decomposition are probably formed by a splitting up of the aconitic acid, thus:—

$$\underset{\text{Aconitic Acid.}}{C_6H_6O_6} = \underset{\text{Acetone.}}{C_3H_6O} + 2CO_2 + CO.$$

Itaconic acid is also produced when citric acid is heated with water for several days in sealed tubes to a temperature of 160° C.

Fungoid growths make their appearance in an aqueous solution of citric acid when it is kept for any length of time, and when mixed with chalk and exposed to a temperature of about 25° C., with a little yeast, fermentation sets in, and the calcium citrate becomes converted into acetate and butyrate. Sulphuric acid, at a temperature of 30° C., eliminates water from the acid, and carbonic oxide is evolved; at a higher temperature, acetone and carbonic anhydride are produced. Fused with caustic potash, citric acid is decomposed into oxalic and acetic acids, thus:—

$$\underset{\text{Citric Acid.}}{C_6H_8O_7} + \underset{\text{Water.}}{H_2O} = \underset{\text{Oxalic Acid.}}{C_2H_2O_4} + \underset{\text{Acetic Acid.}}{2C_2H_4O_2}.$$

When citric acid is heated with peroxide of manganese mechanically suspended in water, carbonic anhydride and acetic acid are formed; with red oxide of mercury it produces effervescence, with the production of acetic acid; and with chloride of gold reduction occurs without any evolution of gas.

Citric acid is readily oxidized by potassium permanganate to acetone and carbonic anhydride. According to CHAPMAN and SMITH, however, a strongly alkaline solution of potassium permanganate is reduced by the citrate only to the state of

manganate, the liquid acquiring a permanent green colour; tartaric acid, under similar circumstances, completely destroys the colour, thus furnishing a means of distinguishing between these two acids. Bromine readily decomposes potassium citrate, carbonic anhydride is given off, and bromaform, $CHBr_3$, and a crystalline body, bromoxaform, $C_3HBr_5O_2$, are produced. With chlorine the action is more complicated, various oily substances besides chloroform being produced.

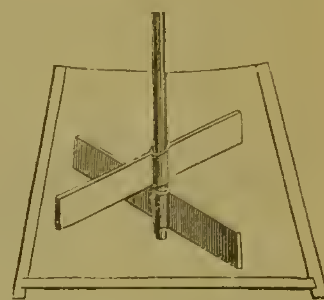
Manufacture.—This acid is prepared by a few firms from the juice of lemons, which is imported in a concentrated state, principally from Sicily and the south of Italy, in casks containing each from 105 to 110 gallons. The bergamot juice of South Italy is also imported for this purpose. Lemon juice is often adulterated with acids, common salt, &c., the former of which, were it tested by the amount of alkali a certain quantity would neutralize, would give a good percentage; while the latter is added to increase the specific gravity, since in many establishments it is examined by means of the *citrometer*—which is nothing more than a hydrometer marked for this particular purpose—and thus the same object is attained. The density of the juice is also often rendered much greater by the carbonization which has occurred during its evaporation; for these reasons, and also on account of the variation in the amount of earthy salts and of saccharine matter, the specific gravity test can scarcely give an approximate result as to the real quantity of acid contained in the sample. For the reasons above mentioned, even the neutralization of a certain weight of alkaline carbonate is a doubtful means of estimation, unless the juice has been previously examined for other acids, and their percentage ascertained.

Sicilian lemon juice is expressed from the damaged fruit, windfalls, &c., and in its unconcentrated state contains between 8 and 9 ounces of free citric acid per gallon. The quantity of free acid in the juice expressed from the fine lemons imported to this country is much higher, however, being between $10\frac{1}{2}$ and $12\frac{1}{2}$ ounces per gallon. The Sicilian juice, after being expressed, is boiled down in copper pans until it has a density corresponding to about 60° on the citrometer, or specific gravity 1·234, each degree on the citrometer corresponding to an increase in the specific gravity of ·004. It is then a dark brown syrupy liquor, containing free acid equivalent to about 64 ounces of citric acid per gallon, or 32 per cent., and besides this, 6 or 7 ounces of combined acid. Of the total acids present, an amount varying from 5 to 11 ounces in various samples of juice, consists of organic acids other than citric.

The process followed for its manufacture on the large scale does not essentially differ from that of preparing small quantities, except as regards the utensils.

The juice to be operated upon is conducted into the decomposing tuns by tubular pillars provided with stopcocks, which communicate with cisterns in the apartment above, into which the contents of the casks are emptied. When the tuns are nearly filled, a sufficient quantity of carbonate of lime is added, previously well ground, and the agitators are kept in constant motion by the machinery above the tun, worked by steam power, until the precipitation of the acid as calcium citrate is completed. Fig. 2 is a section of the tun, showing the agitators in the interior. The mixture, however, is always distinctly acid, even when a large excess of chalk has been added. This was formerly attributed partly to the presence of acid calcium citrate, and partly to a similar alumina compound, but Mr. R. Warrington has found that there is no difficulty in neutralizing pure citric acid with chalk in the cold, even when alumina is present. A solution of phosphoric acid, or phosphate of iron in citric acid, however, cannot be neutralized by chalk; and as the concentrated lemon juice invariably contains a good deal of phosphoric acid and a little iron, it is probable that the difficulty experienced in neutralizing the acidity must be attributed to the presence of these substances, or at least to a great extent. The whole of the acid may, however, be precipitated by the addition of milk of lime until the mixture becomes neutral, but the mucilaginous matters thrown down at the same time interfere so much with the subsequent operations, that it is far more advantageous not to add the lime.

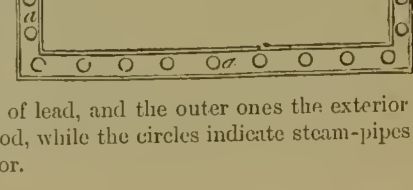
Fig 2.



When the action is terminated, the precipitate is allowed to subside, and the supernatant liquid is drawn off. The citrate of calcium is then washed by stirring it up with water, allowing it to settle, and again drawing off the clear liquor; but, as it is very liable to ferment and decompose, especially in warm weather, the washing must be carried on as rapidly as possible. It is now ready for decomposition by sulphuric acid, 9 parts of oil of vitriol diluted with 56 parts of water being used for every 10 parts of the citrate. When this has been done, the whole contents of the tun are run off by pipes into vats, which retain the sulphate of lime, while the solution of citric acid flows into steam evaporators, where it is concentrated.

One of these evaporators is shown in section in Fig. 3, in which the two inner lines represent the

Fig. 3.



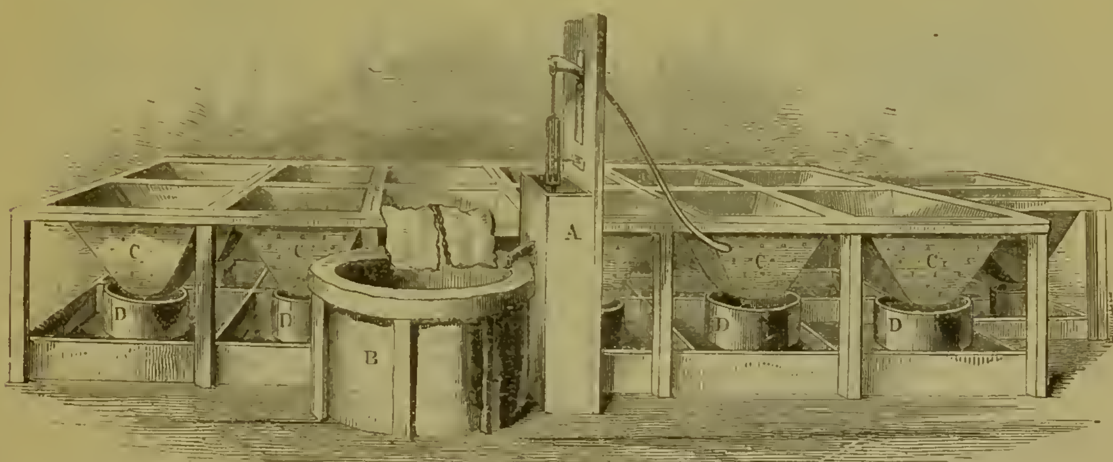
lining of lead, and the outer ones the exterior casing of wood, while the circles indicate steam-pipes in the interior.

When the solution is sufficiently concentrated, it is drawn off by means of a pump, A (Fig. 4), into the cistern B, whence it is put into lead pans, similar to D, and allowed to crystallize. The supernatant liquor is then withdrawn for further concentration, the crystals dissolved, and the solution ladled into the filters, C C, which are lined with lead, the sides being pierced in numerous places. Each of these is supplied with a quantity of animal charcoal, which not only decolorises the fluid, but deprives it of its mechanical impurities. On percolating, it is received into the crystallizing pans, D D, in which it is allowed to stand until the crystals cease to form, or do so only very slowly. The mother liquor is again returned for evaporation. Two or three re-solutions and recrystallizations may be requisite to obtain an article of superior size and purity.

Solutions of citric acid are very liable to change during concentration; and the deepening colour and strongly empyreumatic acid smell indicate the loss which is sustained by conducting the evaporation in open steam pans. A great improvement was introduced in 1856 by Mr. E. A. PONTIFEX, who patented an apparatus for evaporating these solutions *in vacuo*. In this apparatus the temperature does not rise above 120° to 130° Fahr., and possesses the additional advantages that access of air is prevented, the time necessary for evaporation is diminished to one-eighth or one-tenth, and the strong ebullition keeps the liquid constantly in motion. In the ordinary system of evaporating by a steam coil, the movement in the dense solution is so slight, that a portion is left in contact with the steam pipes at a temperature approaching 220° Fahr. for a long time.

The apparatus consists of a leaden vessel, in which the acid liquors are evaporated, inclosed within an exhausted vessel, so that the pressure may be relieved from both the exterior and interior surfaces of the leaden vessel, or the exhaust vessel may be lined with lead, by dressing it down upon the outer vessel with some cement between them; or it may be made of an enamelled iron, which will not be affected by

Fig. 4.



the acid, in which case the lining of lead is unnecessary. The overflow vessel contains a quantity of chalk, milk of lime, or some alkaline solution, through which the steam from the vacuum pan is conducted by means of a wide pipe terminating in a rose. Above the surface of the milk of lime is a priming plate, perforated with numerous holes, through which the steam can readily escape, but which will prevent the liquid being carried over mechanically by the violence of the agitation. The object of this vessel, which is furnished with suitable gauges and pipes for the supply of fresh or the discharge of spent solution, is to retain any volatile acids, such as acetic, butyric, or sulphurous, which would otherwise pass over and injure the apparatus. The overflow vessel would also collect any citric acid solution which might accidentally pass over from the evaporating vessel. The steam may be removed by the ordinary injection condenser; but the inventor prefers PONTIFEX's patent condenser, both on account of the economy of water required to work it, and also because the whole of the products of evaporation may be conveniently collected, and any loss of citric acid readily detected.

In order to prevent any leakage in the valves and cocks attached to the vacuum pan which might be caused by the action of the acid, the body of the valve is made of cast iron, lined with lead, and the valve face and disc are made of india-rubber. The spindle is protected from the action of the acid by a covering of lead.

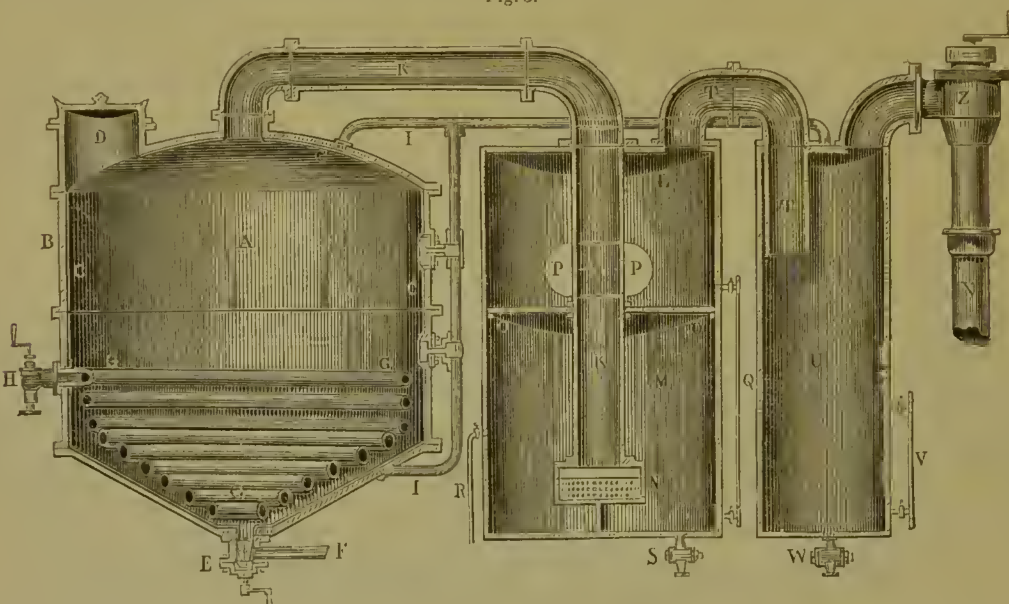
Fig. 5 represents a sectional elevation of this apparatus; A is the vacuum pan, consisting of a cast-iron body, B, lined with lead, C C C; D is the manhole; and E, the valve at the bottom, for discharging the contents of the vacuum pan through the pipe, F. The acid solution, which is charged into the vacuum pan, is evaporated by means of the steam coil, G G G, into which steam is admitted by the valve, H; I I are pipes for exhausting the space between the leaden lining, C, and the outer cast-iron case, B; K K is the wide tube communicating with the overflow

vessel, L M, and which is terminated in the rose, N; O O is the priming plate, which separates the upper and lower portions of the overflow vessel, and prevents the milk of lime from being carried over mechanically into the other portions of the apparatus; P P is the manhole; Q is a glass gauge, and R and S are cocks, the former to supply fresh absorbing solution, and the latter to draw off that which is spent. The upper portion of the overflow vessel, L, is connected by means of a tube, T T, with a safety vessel, U, likewise furnished with a gauge, V, and a discharge cock, W; X is the pipe communicating with the condenser and air-pump, and which can be cut off when required by means of the screw valve, Z.

Various modifications of the process of manufacture have been proposed, but as yet none of them have superseded that above described. KUHLMAN suggests saturating the hot lemon juice as far as possible with very finely-divided barium carbonate, and afterwards to complete the neutralization with barium hydrate or sulphide. The precipitate of barium citrate is then washed, and decomposed with the requisite quantity of sulphuric acid. The advantage of this method is, that the citric acid solution obtained in this way crystallizes more readily than when lime is employed as the precipitant. Sulphate of baryta is quite insoluble in solution of citric acid, whilst sulphate of lime is not, and the latter hinders the crystallization of the acid.

Dr. PRICE obtains a comparatively pure citrate of lime or baryta by neutralizing the lemon juice with an alkali, filtering from the mucilaginous precipitate,

Fig. 5.



and then throwing down the citric acid as a citrate by means of a salt of lime or baryta. The citrate, after being washed, is decomposed in the usual way.

The juice may also be defecated to a considerable extent, according to Mr. ROW, by simply diluting it with water until it contains about 12 ounces of acid per gallon, and then filtering from the flocculent precipitate of mucilage thus thrown down. The citrate of lime precipitated from the dilute juice is comparatively pure.

In the manufacture of citric acid, the observation was made a long time since, that citrate of lime could not be preserved. It decomposes, and no longer yields citric acid—carbonic acid being a product of the decomposition, which remains behind in combination with the base; the nature of the change, however, was not known until PERSONNE examined the metamorphosis. He finds that it is a true fermentation, in which the citric acid splits up into acetic, butyric, and carbonic acids, with evolution of hydrogen.

When clarified lemon juice is saturated with lime, and a glass tube adapted to the vessel containing this mixture, it will be found that in the course of two days, at a temperature between 86° and 95° Fahr., gas is eliminated, and continues to be given off until the citrate is completely changed. Crude lemon juice undergoes this decomposition much more quickly than the clarified juice, but citric acid is still more speedily decomposed if mixed with citrate of lime and beer yeast.

The liquid in which the citrate of lime has disappeared gradually acquires the disagreeable odour of the butyric fermentation. It evolves a mixture of carbonic acid and hydrogen, in which the relative proportion of the one gas to the other, from the beginning to the end of the process, continually varies. The lime salts which are dissolved in the liquid, and which may be obtained by evaporation, yield argentic butyrate and acetate, if converted into the corresponding silver salts. The decomposition which takes place may be thus represented—

$$4C_6H_8O_7 + 2H_2O = 3C_2H_4O_2 + 2C_4H_8O_2 + 10CO_2 + 8H.$$

On account of the readiness with which moist citrate of lime is decomposed, it is impossible to prepare it on the spot from the lemon juice and then import it to this country for the manufacture of citric acid. M. PERRET has suggested, however, that the fresh lemon juice might be saturated with magnesia, which is abundant in many parts of Italy, and the insoluble citrate of magnesia thus obtained could readily be dried without undergoing decomposition, and in that state resists the action of a damp, hot atmosphere for a long time.

An improvement on this method, also devised by M. PERRET, is to convert the insoluble citrate of magnesia into a bibasic citrate. In order to effect this, one portion of the juice is precipitated with magnesia, and the insoluble tribasic citrate of magnesia thus formed is dissolved in another portion of hot lemon juice equal in quantity to that precipitated. After separating the insoluble matters by filtration or subsidence, the solution is concentrated in shallow evaporating pans until it attains a density of 23° Baumé. It is then allowed to cool, and in about twelve hours' time bibasic citrate of magnesia begins to come out. It crystallizes but slowly, requiring in some cases ten days before the whole of the salt is deposited.

In different states of purity citric acid is used extensively by calico-printers. In medicine, it is employed as a substitute for lemon juice, in the preparation of refrigerant drinks and effervescing draughts, and as an anti-scorbutic, anti-narcotic, and anti-alkaline.

As regards its physiological effects there are various opinions. ORFILA, for example, ranks it among the irritant poisons; whilst CHRISTISON and others gave drachm doses of it to cats, without observing that the animals suffered any inconvenience. Small quantities of it in water form an agreeable beverage, which allays thirst, diminishes preternatural heat, checks profuse perspiration, and promotes the secretion of urine.

ADULTERATION.—Citric acid and lemon juice are sometimes adulterated with tartaric acid, and to a very large extent. The best way to detect this fraud when the sophistication is considerable, is to dissolve a given weight of the acid in water, and to add gradually to it a solution of potassa, stirring briskly; crystals of acid potassium tartrate will fall or appear on the sides of the vessel, if any appreciable amount of the adulterant be present. If the quantity of tartaric acid be small, the solution of citric acid must be concentrated, and instead of employing potassa, chloride of potassium, or nitrate of potassium—all of which are serviceable when delicacy and accuracy are not required—use potassium acetate or citrate, which, being deliquescent, may be added at once, without being dissolved, to the suspected solution.

When citric acid attracts moisture on exposure to the air, it is a proof that it retains a small portion of the sulphuric acid used in its preparation, which is very readily detected by dissolving in water, adding hydrochloric acid and chloride of barium. If a white precipitate or milkiness is produced, sulphuric acid is present. Re-crystallizing several times will at once purify it. Tartaric and sulphuric acid are often mixed with the raw lemon juice; and it is a fact, however unpleasant to mention, that hundreds of ships sail from Liverpool and London with an article sophisticated with *oil of vitriol*, &c. Mr. THIN remarks that this adulterated article, on account of its intense acidity, meets with more approval from the common palate than the agreeable acerbity of the genuine juice.

COAL TAR DISTILLATION.—The constituents of the tar obtained by the destructive distillation of coal vary much, both in their nature and their relative proportions, not only with the nature of the mineral distilled, but with the average temperature employed in the distillation. As a rule, the lower the temperature the larger the yield of liquid and solid products, and the less the amount of gas formed, and the higher its illuminating power. Towards the end of the gas-making operation, when the contents of the retorts are heated to a maximum, little but hydrogen is evolved; but in the earlier stages there are produced hydrocarbons and oxidized matters, some permanent gases, some readily combustible vapours, some solids at the ordinary temperature, together with sulphurized and nitrogenous bodies. For the description of the products obtained by the distillation of coal and analogous substances at low temperatures, *vide* the articles PARAFFIN, PARAFFIN OIL, in Vol. II., the present article merely referring to that variety of tar which is obtained during the distillation of gas coal for illuminating purposes.

According to the kind of coal used, and the way in which the gas-making is conducted, a tar is obtained differing somewhat in properties. Thus, cannel coal distilled at low temperatures gives a tar lighter than water, and not readily drying in the air (LETHEBY); ordinary gas coal, as distilled in the provinces, gives a tar heavier than water and readily drying in the air; whilst London coal tar, being produced at a higher temperature still, is still heavier; moreover, it is less in quantity, and is deficient in the more volatile constituents, whilst it contains much naphthalene.

The main constituents of coal tar may be thus classified:—

(A) HYDROCARBONS.

1. Of the Marsh Gas Family:—

Marsh gas,	CH_4	Existing as gases dissolved in the tar.
Higher homologues,	?	
Pentane,	C_5H_{12}	More than one isomeride.
Hexane,	C_6H_{14}	"
Heptane,	C_7H_{16}	"
Octane,	C_8H_{18}	"
Decane,	$C_{10}H_{22}$	"

And probably others constituting solid paraffin.

2. Of the Olefine Series:—

Olefiant gas,	C_2H_4	Existing as gases dissolved in tar.
Propylene, (?)	C_3H_6	
Tetrylene, (?)	C_4H_8	
Amylene,	C_5H_{10}	
Hexylene,	C_6H_{12}	
Heptylene,	C_7H_{14}	

And probably others.

3. Of the Benzene Family:—

Benzene, ... C_6H_6
Toluene, ... C_7H_8
Xylene, ... C_8H_{10} } Possibly other isomerides.
Isoxylene, ... C_8H_{10} }
Pseudocumene, ... C_9H_{12} } "
Mesitylene, ... C_9H_{12} }
Tetramethyl benzene, ? .... } $C_{10}H_{14}$ "

4. More highly Carbonized Hydrocarbons:—

Styrolene, ? .... C_8H_8
Naphthalene .... $C_{10}H_8$
Naphthalene hydride, (?) $C_{10}H_{10}$
Acenaphthalene, ... $C_{12}H_{10}$
Anthracene, ... $C_{14}H_{10}$
Phenanthrene, ... $C_{14}H_{10}$
Pyrene, ... $C_{16}H_{10}$
Chrysene, ... $C_{18}H_{12}$
Chrysodene, ... ?
Bitumene, ... ?
Benzerythrene, ... ?
And others less fully investigated.

(B) SUBSTANCES CONTAINING OXYGEN.

Water, ... H_2O
Wood spirit, ? .... CH_4O
Acetic acid, ... $C_2H_4O_2$
Compound ethers, ... Various.
Phenol (carbolic acid), .. C_6H_6O
*Creosol, ... C_7H_8O { More than one isomeride (?)
Higher homologues.
Besolic acid, ... ?
Brunolic acid, ... ?

(C) SULPHURIZED SUBSTANCES.

Ammonium sulphide, or sulphydrate.
" sulphocyanide, ... $NH_4.CNS$
Carbon disulphide, ... CS_2
And probably other bodies.

(D) NITROGENOUS BODIES.

(1.) Ammonia series:—

Ammonia, ... NH_3
Methylamine, (?) .. NCH_5
Higher homologues, .. . ?

(2.) Pyridine bases:—

Pyridine, ... C_5H_5N
Picoline, ... C_6H_7N
Lutidine, ... C_7H_9N
Collidine, ... $C_8H_{11}N$
Parvoline, ... $C_9H_{13}N$
Coridine, ... $C_{10}H_{15}N$
Rubidine, ... $C_{11}H_{17}N$
Viridine, ... $C_{12}H_{19}N$

(3.) Leukoline bases:—

Leukoline, ... C_9H_7N
Lepidine, ... $C_{10}H_9N$
Cryptidine, ... $C_{11}H_{11}N$

(4.) Pyrrol, ... C_4H_5N

(5.) Aniline bases:—

Aniline .... C_6H_7N
Toluidine, (?) .... C_7H_9N
Higher homologues, ... ?

(6.) Cyanogen compounds.

(7.) Other nitrogenous constituents:—

Acridine, ... $C_{12}H_9N$ (or $C_{21}H_{14}N_2$)
Carbazol, ... $C_{12}H_9N$

(E) NON-VOLATILE MATTERS, CONSTITUTING PITCH.

Many of the substances in the above list do not exist as such in the tar, but are formed during the further distillations to which the tar is subjected.

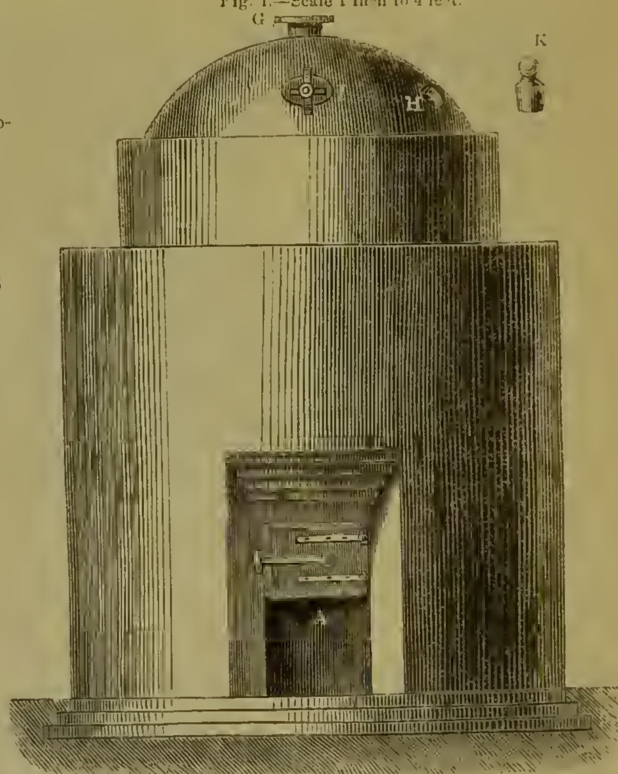
* Creosote proper has the formula $C_8H_{10}O_2$, and is wholly different from the creosol or cresylic alcohol of coal tar.

Of these numerous bodies only a few are extracted for commercial purposes, those mostly in demand being:—

Ammonia,
Benzene and its homologues,
Carbolic acid,
Naphthalene,
Anthracene,
Pitch.

The ammonia is mainly present dissolved in the aqueous liquor which is formed during the distillation of coal, and which is only incompletely separated by mechanical means from the tar; for the methods employed in the utilization of this liquor *vide* article AMMONIA. The crude ammonia liquor often contains inflammable gases dissolved, which burn without smoke.

Fig. 1.—Scale 1 inch to 4 feet.



The different constituents of the coal tar are separated by distillation, the various fractions of distillate obtained being subjected to further purifying processes. Owing to the magnitude to which the manufacture of coal tar products has now attained, the first rough distillation of coal tar has come to constitute a distinct trade of itself, the various crude products manufactured and sold by the coal tar distiller being usually refined by the purchaser: the processes adopted in these refining operations are described under the headings BENZOL, CARBOLIC ACID (DISINFECTANTS), and further on under *Anthracene*, &c. At present we confine ourselves to the preparation of the crude substances.

This preparation, as usually carried on in the

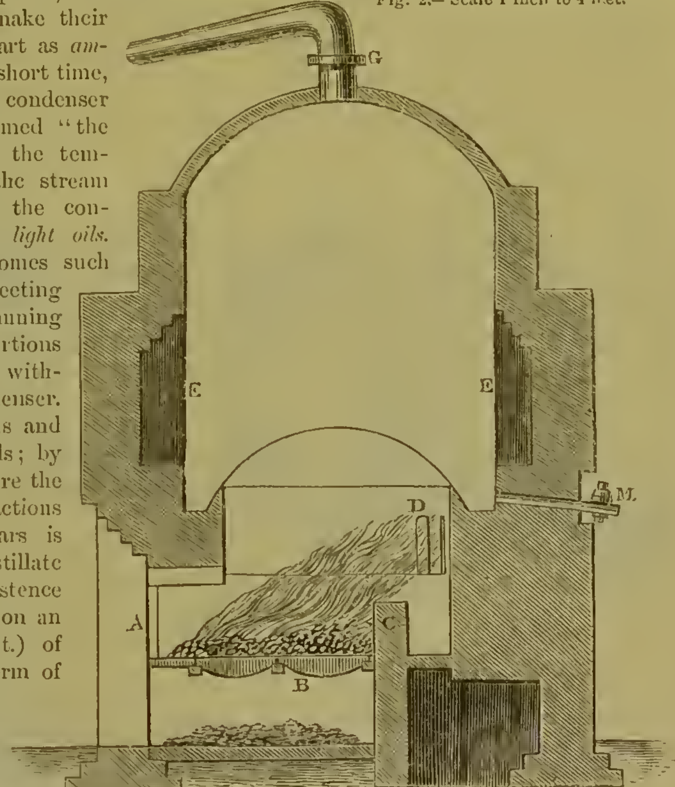
vicinity of London, may be thus generally described:—The coal tar is allowed to stand in large tanks, so that as much ammoniacal liquor as possible shall separate mechanically by rising to the surface; the heavier tar is then pumped off from the bottom of the tank into a still, where it is heated. Permanent gases, water charged with ammonium sulphide, and the more volatile portions of the tar make their appearance at first, and are collected apart as *ammoniacal liquor* and *first light oils*. After a short time, the stream of liquids running from the condenser slackens and almost ceases; this is termed "the break," and lasts for a short time until the temperature of the still rises somewhat: the stream then recommences, what escapes from the condenser being collected apart as *second light oils*. When the density of the distillate becomes such that the liquid sinks in water, the collecting recipient is again changed, the oils now running being known as *creosote oils;* the first portions of these contain much naphthalene, which without due care is apt to block up the condenser. Later on, the naphthalene present lessens and is kept wholly in solution by the liquid oils; by and bye the distillate begins again to acquire the property of thickening on cooling; the fractions collected after this phenomenon appears is known as *anthracene oil*. When the distillate is semi-solid on cooling (about the consistence of butter), the operation is concluded; on an average, about two-thirds (67 per cent.) of the tar is then left in the still in the form of pitch.

Before the discovery of the process of manufacture of alizarin from anthracene, the last portions of distillate were useful for little but the production of lubricating materials; the distillation was then carried on to a point dependent on the nature of the pitch required (hard or soft). At the present day it is an object to carry the distillation as far as possible, so as to obtain the maximum yield of anthracene; if, however, it is required to sell the pitch, the distillation must not be pushed too far, otherwise the pitch becomes "coked" and worthless as pitch. When, however, it is requisite that this should be done, it is necessary to perform the coking distillation in a separate vessel, so as to diminish the difficulty and expense of extracting the residual coke from the still: special stills have been constructed for this purpose.

In some works in Scotland the tar is first heated in a still provided with a steam jacket, or steam is blown through the tar till the more volatile products are expelled. All that can be got off by steam heat is then sold for the purpose of extracting benzol (*q. v.*); the residue, known as "boiled tar," is then run into another still heated by a free fire and distilled; the second light oils and subsequent fractions being collected as above. These light oils are largely used for burning purposes. On the Continent, too, the tar is frequently heated in a vessel provided with a steam jacket, so as to cause the separation of watery liquor (*vide infra*); the dehydrated tar is then run off and distilled over a free fire.

The first and second light oils are worked up for benzol, solvent naphtha, and carbolic acid. From the creosote oils, more particularly the lower half, naphthalene separates in quantity on standing; this is collected on coarse woollen sackcloth, or wire gauge filters, and squeezed by hydraulic or other pressure, and sold as crude naphthalene.

Fig. 2.— Scale 1 inch to 4 feet.



The anthracene is separated from the anthracene oils in just the same way, and is rarely subjected to any purifying process by the tar distiller himself. The modes of purifying this crude product, its valuation, &c., will be described below.

The following diagrams and description of the usual disposition of a London tar still, and its appliances, with the annexed description of the usual method of working it, were obligingly forwarded to the writer by Mr. A. J. Dickinson.

Fig. 1, front elevation; Fig. 2, section from front to back; Fig. 3, plan; Fig. 4, plan of top of still. A, furnace door; B B, fire-bars; C, bridge; D D D D, openings into flue; E E, circular flue, with stop at L; F, exit to chimney; G, still head; H, charging hole closed with conical plug, K; I, manhole; K, plug for closing charging hole; L, stop in circular flue; M, pitch-cock.

A still holding about 1200 gallons is to be preferred, as this charge can be worked off in ten to twelve hours, thereby avoiding the necessity of night-work; larger sizes, however, are frequently used. The relative disposition of the plant in a tar

work of course depends much on the nature of the ground and other circumstances, but, as a rule, the still should be placed as near the tar tank as possible; and the connecting pipe between the still head and the condensing worm should be placed on the opposite side to the furnace door, so that in case of a pipe breaking there might be time to damp out the fire before the issuing vapours reach the furnace. Similarly the cock for withdrawing the hot liquid

Fig. 3.—Scale 1 inch to 4 feet.

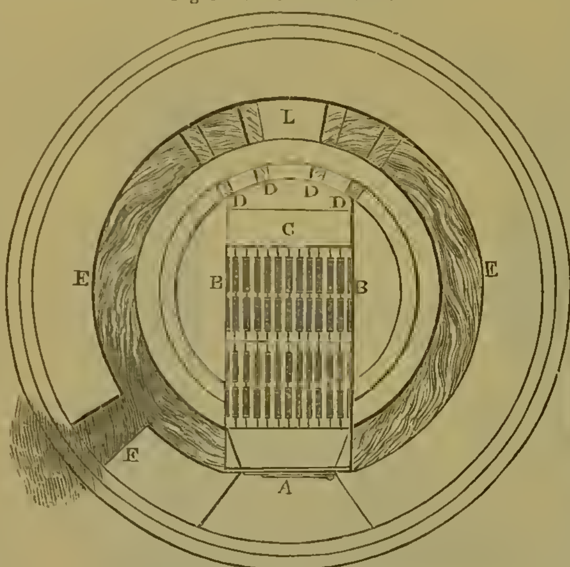
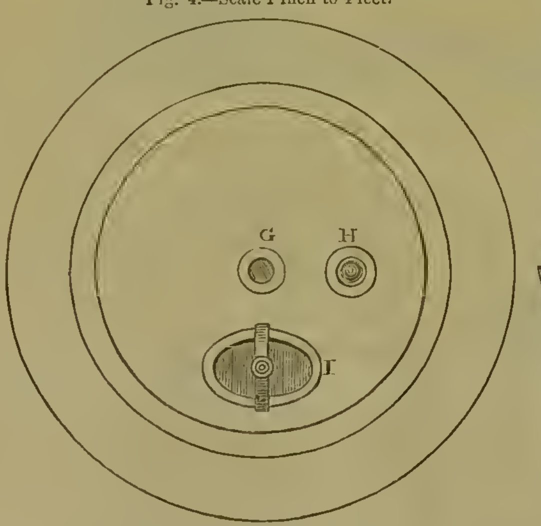


Fig. 4.—Scale 1 inch to 4 feet.



pitch is placed on the side opposite to the furnace, to avoid the chance of firing the vapours evolved as the hot mass flows out to the pitch tank.

The condensing worm is usually a 4-inch socket pipe in 6 and 9 feet lengths with elbows, arranged in a rectangular tank; about 140 feet total length is usually sufficient for this size of still, but a thoroughly efficient condensing arrangement is most essential.

The following is a description of a day's working. About 6 a.m. the still is charged with about 1200 gallons of tar, and the fire is lighted; in about an hour the tar begins to rise in the still, and the fire requires careful watching, being slacked and increased as required, until the distillation commences (which it does about two hours after the fire is lighted).

The first portion of distillate consists of gases, ammonia water, and first light oils (naphtha); when about 60 to 70 gallons have passed over (containing about 20 to 25 of naphtha and the rest water), the "break" occurs (called so from the fact that the still almost ceases working); with the above mentioned size of still this usually lasts for an hour, or an hour and an half, during which time little but water passes over, the generation of steam being accompanied by a peculiar noise, so that the still is said to be "on the rattles" during this period. When the temperature has increased sufficiently, the still "comes off the rattles," and throws off about 20 gallons of oil lighter than water. The point at which the distillate begins to be heavier than water is readily found by simply collecting some of the distillate, and noticing whether the oil or the aqueous portion rises to the top. As soon as the oil sinks to the bottom of the water, the shoots are changed, and the still is said to be "on the oil:" this point can also be told by the colour of the oils, the second light oil looking whiter, and having a thread of reddish water running off along with it. About 300 gallons more are then distilled off, which requires about three hours; of this the first portion chiefly consists of naphthalene, and at this point particular attention must be paid to prevent blocking up of the worm. When about 150 gallons have run off the nature of the products changes, and the still is said to be "on the soft oil," the naphthalene being wholly soluble in the liquid oils then running; the oils at this point are called "sharp soft oils." After this the oil begins to thicken on cooling; the approach to this point is tested by simply catching a little of the oil on a piece of iron; the still is then said to be "on the

K

anthracene oil"—about 50 gallons of the 300 consist of this. When the oil sets to about the consistence of butter on the iron, the fire is withdrawn. This stage is reached about 5 p.m.; the residue in the still then consists of coal-tar pitch, weighing about 4 tons.

The average produce from 1200 gallons of tar (about 6 tons) is—

Ammoniacal liquor,	about 50 gals.	= about 4 p.c.	by weight.
First light oils,......	" 20 "	" 1·5	"
Second light oils,...	" 20 "	" 1·5	"
Creosote oils,........	" 250 "	" 22	"
Anthracene oils,....	" 50 "	" 4	"
Pitch,................	" 4 tons	" 67	"
		100	

The above quantities fluctuate somewhat according to the quality of the tar.

From the 50 gallons of anthracene oil about 1 cwt. of crude anthracene (at 30 per cent.) is obtained by standing and pressure; the liquid oils, from which the solid anthracene separates, serve for the preparation of lubricating grease, &c.

Lunge describes the following form of still as

frequently used in Great Britain (Figs. 5 and 6):—The still is constructed of $\frac{3}{4}$-inch boiler-plates,

Fig. 5.

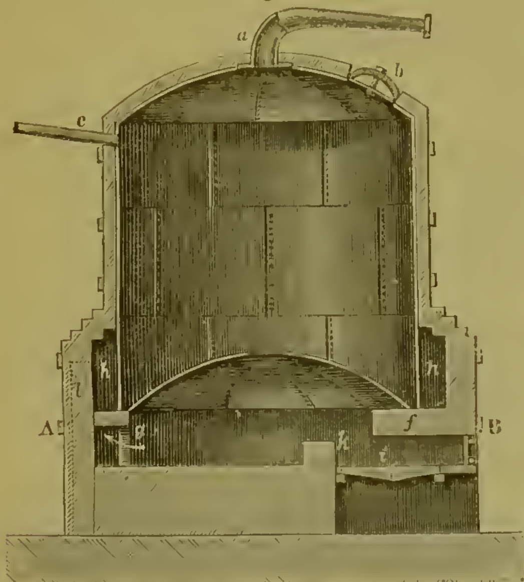
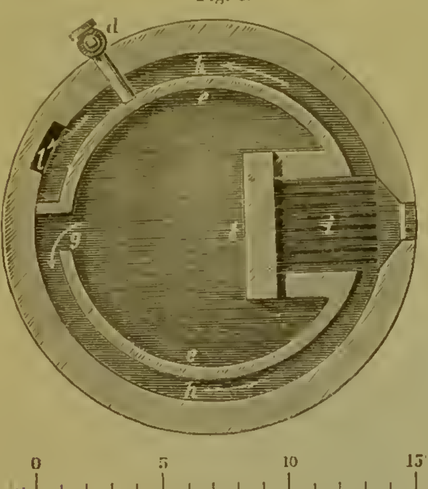


Fig. 6.



Scale in feet.

well rivetted together—*a*, still head, the orifice in the still is 12 inches diameter, the bent neck tapering down to 4 inches clear; *b*, manhole made tight with clay (india-rubber washers cannot be used); *c*, tube for conveying tar to still from tar tank; *d*, exit-pipe for liquid pitch; *e e*, circular sustaining wall on which the still rests; *f*, crown of arch over fire-place, preventing over heating of still in that part; *g*, upcast flue leading to annular flue, *h*; *h h*, annular flue; *i*, fireplace, 4 feet square; *k*, fire-bridge, 18 inches high; *l*, flue to chimney; A B, level at which the horizontal section, Fig. 6, is made.

Other forms of still are, however, frequently used, especially on the Continent. Bolley divides tar stills generally into four kinds ("Technologie," B. V., 2, Braunschweig, 1870).

(A) Cylindrical wrought-iron stills (the diameter of which exceeds the height); with flat or arched bottoms (Fig. 7).

(B) Cast-iron cauldrons of almost globular shape (Fig. 8).

(C) Vertical cylinders of boiler-plate, of greater height than diameter; bottoms concave, roofs convex (Figs. 5 and 6).

(D) Waggon-boilers of D-shaped sections; or horizontal cylindrical boilers (Figs. 9 and 10).

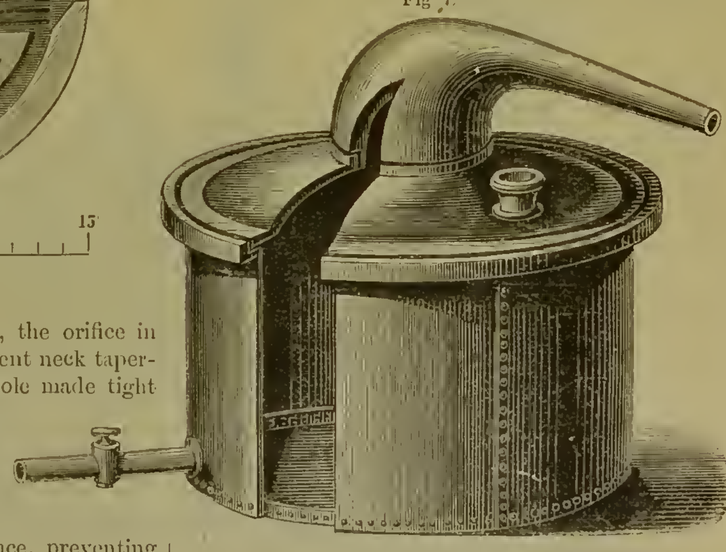
Figs. 9 and 10—A, still protected from direct action of fire by brick arch; *s s s*, flue making $2\frac{1}{2}$ turns round still; *p*, still head; *q*, manhole; *u*, exit-pipe for hot pitch.

Fig. 11 indicates a convenient form of cock for drawing off the hot liquid pitch.

Fig. 12 indicates a form of condenser recommended by Bolley. The upper zig-zags are made of cast-iron pipes, 3 inches in diameter, to diminish the risk of plugging up with solid hydrocarbons; the lower ones are only $1\frac{1}{2}$ inch diameter. At each end of each pipe is a plug fixed tight by a frame and screw, by means of which obstructions can be readily cleared away should they occur, the plug being removed and a cleansing-rod thrust into the pipe; to facilitate this operation the tank in which the condenser is placed is made of smaller dimensions, so that the H-shaped joints project outside its ends.

Some continental distillers employ more than one worm-shaped condenser, differing for each kind of distillate. The first (used for the lightest oils) is made of a much narrower tube than the one employed for

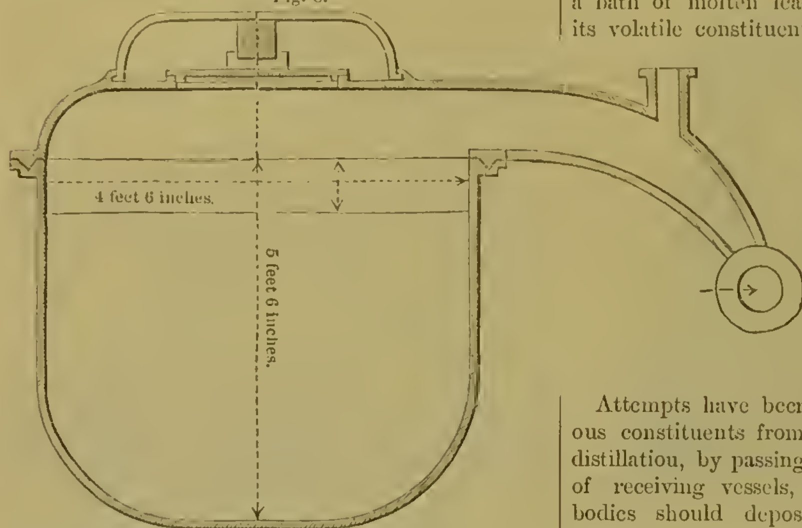
Fig. 7.



the heavy oils, the greater width in the latter case being adopted to diminish the risk of plugging up the condenser by deposition of solid hydrocarbons, &c.; for the same reason, the water round the first condenser is kept as cool as possible by means of a continuous supply of cold water to the condensing tank, whilst that round the condenser for heavy oils is

kept at a temperature of 60° to 70° C. The same result is, however, more conveniently and cheaply attained by employing only one sufficiently wide condensing worm, and regulating the supply of water

Fig. 8.



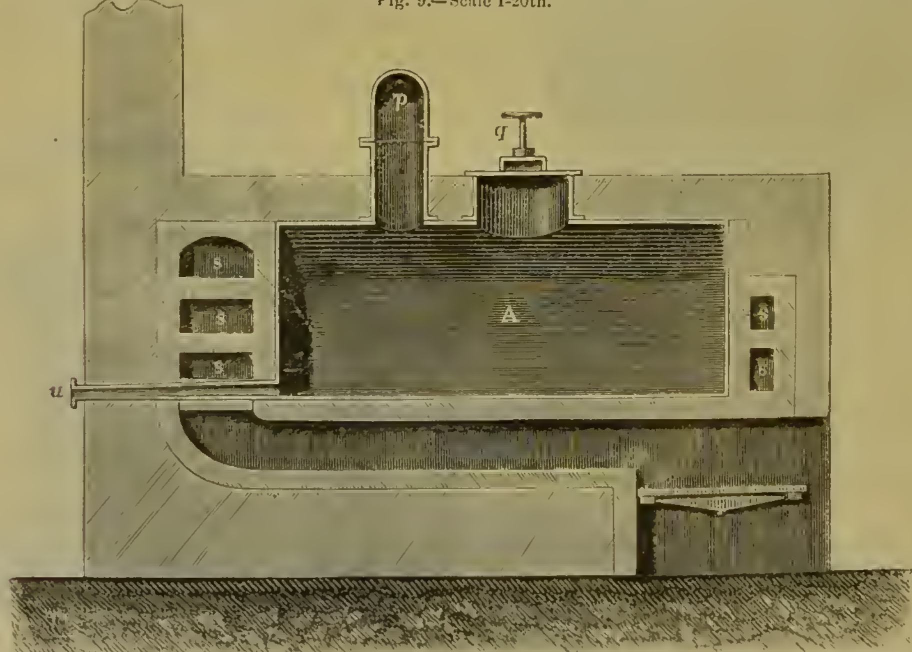
to the condensing tank, so that it is as cold as possible at the commencement of the distillation when the light oils pass over, but becomes warmed up as the heavier oils begin to distil.

Other distillers pass a jet of steam into the still to facilitate the regular disengagement of vapours. Attempts have also been made to make the distillation a continuous process, a stream of tar being made to enter at one end of the arrangement, pitch issuing at the other end. For this purpose MALLET employs a bath of molten lead over which the tar flows, its volatile constituents being expelled during its onward progress, and being separately collected by fixing partitions in the distilling vessel in such a way that the tar can freely flow from one end of the lead-bath to the other, whilst the vapours evolved in different parts kept are separate the one from the other. The economy of this arrangement is, according to KNABE, doubtful.

Attempts have been made to separate the various constituents from one another during the first distillation, by passing the vapours through a series of receiving vessels, so that the less volatile bodies should deposit in the first condenser, and the most volatile in the last, but the results have not been satisfactory, although processes of this kind have given good results when the first crude distillates are redistilled. (*Vide* BENZOL.)

The method for the first rough fractionation of coal

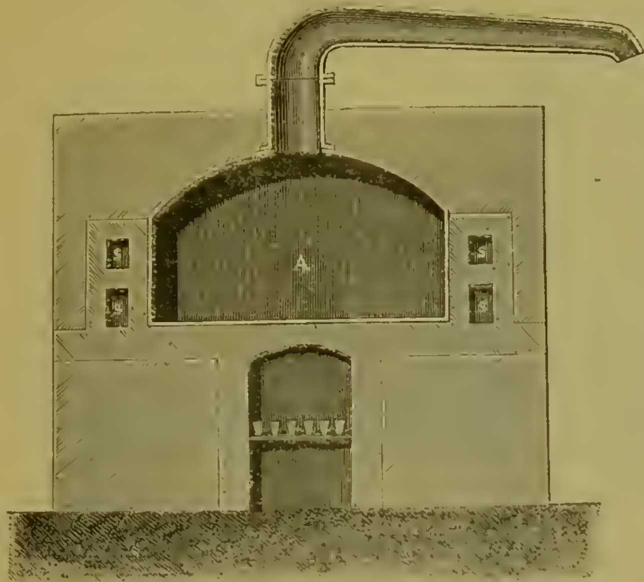
Fig. 9.—Scale 1-20th.



tar practised on the Continent differs from that above described (which represents the process usually employed in England) in several respects. According to this method the separation of the last traces of ammonia liquor from the tar is effected by heating the tar for 20 to 30 hours to from 80 to 90° C., in a large boiler furnished with a condenser, so as to retain any light oils volatilized during the heating. The vessel is sometimes heated by an ordinary furnace, but on account of the great danger from accidental

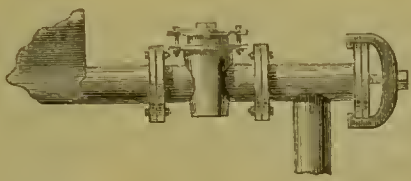
leakage, a steam-jacket or a steam-worm is usually employed.

Fig. 10.—Scale 1-20th.



The tar *floats on the top** of the ammoniacal liquor, which is drawn off by a cock in the lowest part of the boiler, a little of the lower layer of tar (more or less mixed with water) being also drawn off with it.

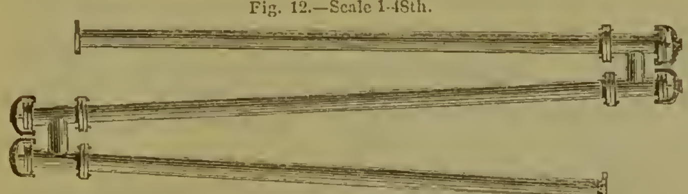
Fig. 11.—Scale 1-24th.



The tar thus freed from water is then pumped, while yet hot, into the still.

This process of separation, or one the same in principle, is described by BOLLEY as extensively used in Germany.

Fig. 12.—Scale 1-48th.



The still recommended as most convenient is a cylindrical one mounted horizontally in brickwork, so that the direct fire does *not* play upon its bottom, the heat being communicated by flues circulating round the lower portion, the highest of these being at no higher an elevation than the level of the residual pitch when the distillation is finished, otherwise the still and its contents are apt to be burnt. In the stills usually employed in England the fire plays *directly upon the bottom.* The flues are provided with dampers to regulate the draught and hence the temperature, and a dome is fixed on the top of the boiler (*still head*), from which issues the tube passing to the condenser (or condensers, if more than one be used). A gutter runs round this dome internally, so that any liquid condensed in the upper portions may run to the condensing worm, and not drop back into the still, as this might at times cause bubbling up and foaming of the contents. The ball of a thermometer is inserted into the dome through an orifice for the purpose, so that the temperature of the thermometer can be read off (the steam being still outside).

The fractions collected are regulated by the thermometer thus:—†

	Density.	Temperature of distillation in degrees C.
First fraction or light oils,	0·78 to 0·85	30° to 140°
Second fraction or medium oils,	0·83 to 0·89	150° to 210°
Third fraction or heavy oils,	0·92 to 0·93 (?)	220° to 350°

The table (on next page) represents a sketch of the treatments to which these various fractions are further subjected in order to obtain from them purified hydrocarbons, suitable for the manufacture of aniline, for dissolving india-rubber, for the manufacture of lubricating oils, &c., according to the nature of the product; the acid and alkaline liquors obtained by the wet treatments being put aside for the extraction of carbolic acid, &c.

It is noticeable that in the process of tar distilling thus described, the anthracene present in the tar is either not extracted at all or only imperfectly. During the last two or three years this substance has acquired a vastly increased importance, so that the efforts of the tar distiller are now directed towards obtaining as large a yield of this hydrocarbon as is consistent with the other objects in view, this table, therefore can only be taken as indicating the treatment of the lower boiling oils obtainable from coal tar (*vide* BENZOL); the pitch produced being of a considerably softer character than that usually prepared at the present time, when the distillation is carried on as far as is practicable without rendering the pitch unsaleable.

* When cold, ordinary tar is heavier than ammoniacal liquor, which floats to the top. In Scotland the tar is often heated in a steam-jacketted still, whereby the first light oils are distilled off. The residue is then run off to another still heated by a free fire, and the distillation finished therein.

† This mode of regulation is not adopted in England, the fractions being distinguished from one another as above described, viz.:—That coming over before "the break" (first light oils); that coming over after "the break," and having a density not greater than that of water (second light oils); that having a density greater than that of water (creosote and anthracene oils = heavy oils). The so-called "heavy oils" of the Continent in no way correspond in sp. grav. to the English heavy oils; they answer more nearly to the English second light oils in this respect.

FIRST DISTILLATION—

COAL.

Gas.	Tar.	Coke.

SECOND DISTILLATION—

TAR.

Crude Light Oils (30°—150° C.).	Crude Medium Oils (140°-200° C.).	Crude Heavy Oils (200°-350° C.).	Pitch.

THIRD DISTILLATION.

Crude Light Oils.	Crude Medium Oils.
Fraction No. 1, Naphtha, passes below 140° C.	Fraction No. 1, passing below 130° C., added to naphtha.
Fraction No. 2, passing above 140° C., added to the medium oils.	Fraction No. 2, rectified medium oil.
	Fraction No. 3, passing above 200 C., added to heavy oils.

TREATMENT BY THE WET PROCESS.

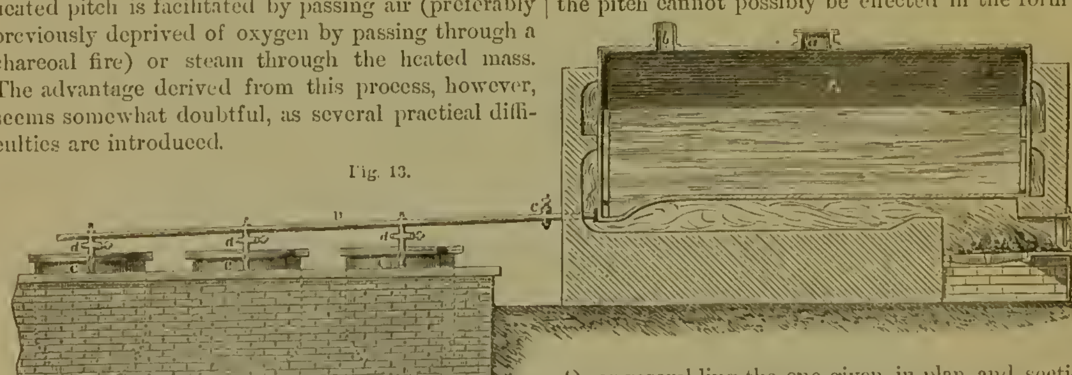
Rectified Light Oils or Naphtha (30°-140° C.).	Rectified Medium Oils (140°-200° C.).	Crude Heavy Oils.
1. Washing with pure water.	1. Washing with pure water.	1. Washing with pure water.
2. " sulphuric acid.	2. " sulphuric acid.	2. " hydrochloric acid.
2. " water.	2. " pure water.	1. " pure water.
1. " soda.	1. " soda.	1. " soda.
2. " water.	2. " water.	2. " pure water.

FOURTH DISTILLATION.

Naphtha.	Rectified and Purified Medium Oils.	Purified Heavy Oils.
Fraction No. 1, passing between 30° and 80° C.	Fraction No. 1, passing between 140° and 190° C.	Fraction No. 1, 215°-230° C.
Fraction No. 2, passing between 80° and 115° C.—Benzol.	Fraction No. 2, passing above 190° C., added to the heavy oils.	Fraction No. 2, 230°-290° C.
Fraction No. 3, passing between 115° and 150° C.		Fraction No. 3, 300°-340° C.
Fraction No. 4, passing above 150°.		

Several patents have been taken out of late years for the production of the maximum possible quantity of anthracene by completely coking the pitch; in some of these, such as those of KOPP, and BRUMER, and GUTZLOW, the evolution of vapours from the heated pitch is facilitated by passing air (preferably previously deprived of oxygen by passing through a charcoal fire) or steam through the heated mass. The advantage derived from this process, however, seems somewhat doubtful, as several practical difficulties are introduced.

Fig. 13.



English still above described, the loss of time and cost of labour in chipping out the solid coke, and the damage thereby done to the still, being too great.

The tar is distilled in a wrought-iron still or boiler similar to the one above described (Figs. 1, 2, 3, and 4), or resembling the one given in plan and section in the annexed engravings (Figs. 13 and 14); the light oils and creosote oils being condensed in the ordinary way in the condenser, B; when the anthracene oils are about to come over, the liquid pitch is run (whilst still hot) into a series of vessels, C C C, in which the coking is effected.

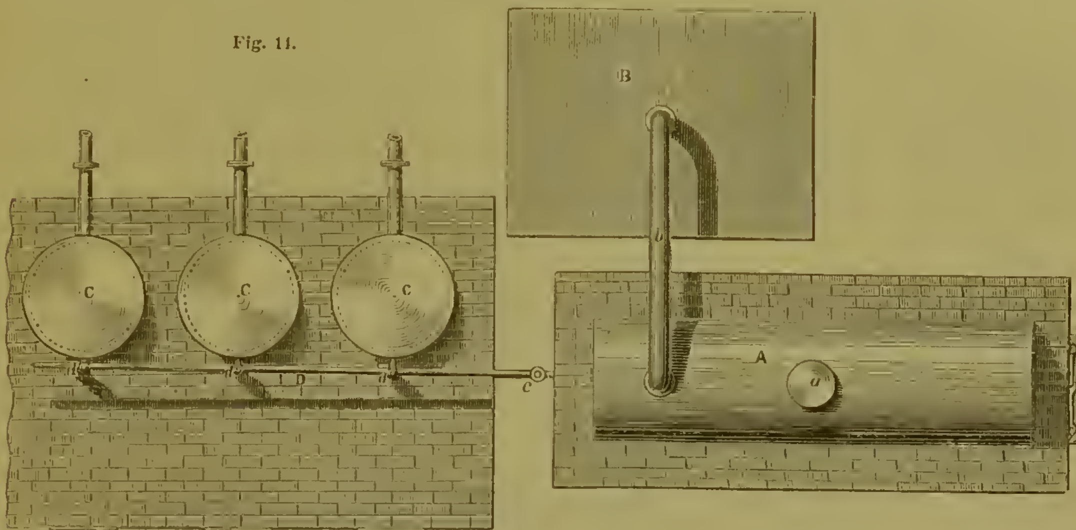
The following distilling arrangement is proposed by FENNER and VERSMANN for the distillation of tar, the more immediate object of the apparatus being to obtain the largest possible yield of anthracene, the pitch being *entirely coked* during the process. Coking the pitch cannot possibly be effected in the form of

A (Figs. 13 and 14), still in which the tar is first distilled; B, tank, with condensing worm for light oils and creosote oils; *a*, manhole; *b*, orifice with

which the condensing worm is connected; *c*, tap whereby liquid pitch is run off into main, D; D, pitch main; C C C, cast-iron pitch stills; *d d d*, taps whereby pitch is run into the stills; *e e e*, delivery pipes for liquid pitch.

These vessels (*a*, Figs. 15 and 16), are made of cast iron, and are about 4 feet diameter, and 4 feet 8 inches deep (internal measurement); it is alleged that, when set in the way indicated in the diagram, they will last five or six years when worked so as to

Fig. 14.

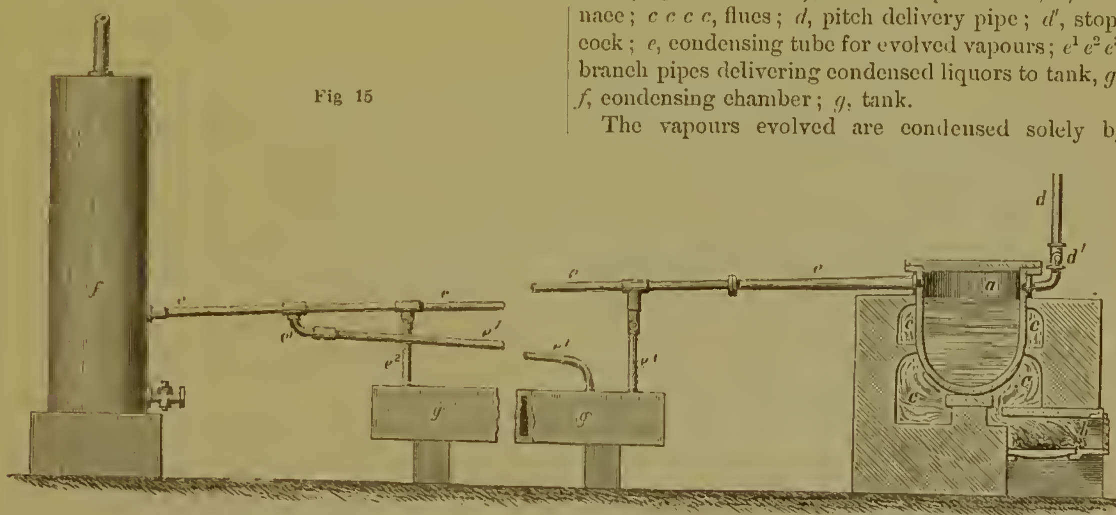


distil off one charge of $1\frac{1}{2}$ to 2 tons of pitch every three days, one day being occupied in the distillation, and two more in the cooling, emptying, and recharging. A production of 10 tons of pitch per day therefore requires three sets of six cast-iron pots each for the coking operation.

a (Figs. 15 and 16), cast-iron pitch still; *b*, furnace; *c c c c*, flues; *d*, pitch delivery pipe; *d'*, stopcock; *e*, condensing tube for evolved vapours; e^1 e^2 e^3, branch pipes delivering condensed liquors to tank, *g*; *f*, condensing chamber; *g*, tank.

The vapours evolved are condensed solely by

Fig 15



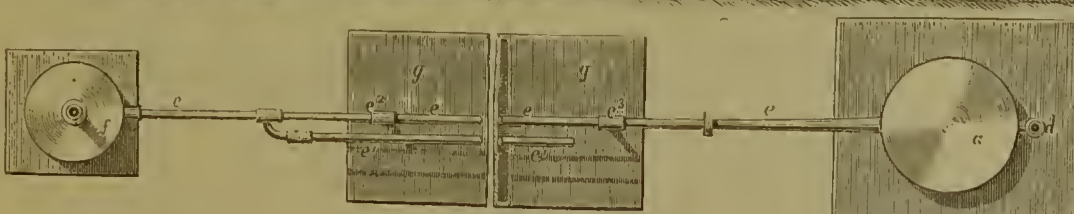


Fig. 16.

atmospheric cooling, partly in the tube, *e*, partly in the condensing chamber, *f*. The evolution of vapour is greatly facilitated by creating a partial vacuum in the pot, *a*, by means of an exhauster or blower attached to the exit of the chamber, *f*, but no advantage is derived by blowing either hot air or steam through the pitch. Towards the latter part of the distillation the branch tubes, e^1 e^2 e^3, are successively opened, so as to provide as short and ready a passage as possible for the escape of the condensed bodies

into the tank, *g*. This is essential, otherwise the vapour-delivery pipe, *c*, is apt to become blocked by the separation of solid matter.

The distillate at 600° to 700° Fahr. (315° to 370° C.) is, according to FENNER and VERSMANN, very rich in anthracene, but little naphthalene or chrysene being therein present; between 500° and 600° Fahr. (260° and 315° C.) the naphthalene is in excess; above 700° Fahr. (370° C.) anthracene is less abundant, chrysene and other bodies of higher boiling point than anthracene being the main constituents of the distillate. On standing, these distillates deposit solid matter, from which rough anthracene is separated by filtration, washing with lighter oils, &c., and pressing.

The cast-iron pots and other plant shown in Figs. 2 and 3 may also be used for the distillation of pitch, purchased as such for the purpose of extraction of anthracene from it. For this purpose the pitch is broken up into small lumps, and preferably mixed with oils arising from a previous distillation, or with dry absorbent carbonaceous matter. The object of this is to prevent frothing, and consequent blocking up of the vapour-delivery tubes on first heating, owing to the presence of moisture in the pitch. The patentees state that, on an average, 2 per cent. of anthracene is thus obtainable from ordinary pitch. As ordinary coal tar yields about 0·5 per cent. of rough anthracene, and 67 per cent. of pitch (this latter corresponding to 1·33 anthracene per 100 of original tar), it results that the production of anthracene is nearly quadrupled when the tar is coked—*i.e.*, 1·85 per cent. altogether is obtained instead of 0·5 per cent., the correctness of the above statement being assumed. It must, however, be noticed, that alizarin makers have recently found that "pitch anthracene" prepared by FENNER and VERSMANN'S process, or by some analogous method, is not well suited for the manufacture of colour on account of the practical inconvenience occasioned by the large admixture with chrysene, &c.: and hence that this article is almost unsaleable in consequence. Several lawsuits have sprung out of this circumstance. The coke which is left in the pots is hard and dense, and being free from sulphur, is very valuable for many metallurgical processes. The oil from which the anthracene is separated is a good lubricator.

KOPP recommends the use of stills of moderate size for the distillation of soft pitch, the expulsion of the vapour towards the end being facilitated by the injection of steam or air into the still, or preferably of a mixture of nitrogen and carbon oxide, produced by forcing air through a red-hot mass of coke.

The quantities of valuable commercial products obtainable from coal tar vary much according to the nature of the original coal, the mode of distillation employed, &c. It is noticeable that, as a rule, when tar is rich in anthracene it is poor in toluene and higher homologues (although containing much benzene), and *vice versa*; and it has hence been argued that anthracene is at least partially formed at the expense of these hydrocarbons. In point of fact BERTHELOT has shown that when toluene vapour is passed through a red-hot tube much benzene and anthracene are formed; the same holds for the mixture of hydrocarbons known as coal-tar xylol; whilst coal-tar cumol (the next higher homologous mixture of isomerides) yields, under the same conditions, little benzene and anthracene, but much toluene. It is probable that the anthracene obtained by the distillation up to coking of pitch does not pre-exist as such in the pitch, but is formed during the heating operation (VERSMANN). As a rule, the more hydrogeneous the coal, the larger the yield of tar from it.

The following estimates have been made as to the average yield of various constituents and products from coal tar.

CRACE-CALVERT.—100 parts of tar of the undermentioned classes contains the following ingredients:—

	Source of Tar.			
	Boghead coal.	Cannel coal.	Newcastle coal.	Stafford-shire coal.
Benzol,	12	9	2	5
Carbolic acid,	3	14	5	9
Heavy hydrocarbons,	30	40	12	35
Paraffin,	41	—	—	—
Naphthalene,	—	15	58	22
Dry tar,	14	22	23	29
	100	100	100	100

PERKIN.—100 lbs. of coal yield—

	Lbs.	Ozs.		Parts by weight.
Tar,	10	12	=	100
Coal-tar naphtha,	—	$8\frac{1}{4}$	=	5
Benzol,	—	$2\frac{3}{4}$	—	1·6

GIRARD AND DE LAIRE.—French tars—

	Parts.
Tar,	100
Liquid pitch,	75—80
"Fat" pitch (soft pitch),	60—70
Dry pitch (hard pitch),	50—60

VERSMANN.—Average English tars—

	Parts.
Coal,	1000
Tar,	45
Pitch,	30
Tar,	100
Pitch,	67
Benzol,	$1\frac{1}{2}$
Anthracene (of from 30 to 60 per cent.),	1·85*
Anthracene (about),	0·5 †

LETHEBY.—English tars:—1 ton of gas coal as distilled in London gives about 9 to 10 gallons of tar: 1 ton of coal as distilled in the provinces gives about 15 gallons of tar: 1000 gallons of London tar yield:—

	Gallons.	Average. Gallons.
Ammoniacal liquor,	20 to 28	24
Crude naphtha (first light oils),	12 to 20	16
Second light oils,	4·8 to 14	12
Creosote oils,	275 to 276	288
	Tons.	Tons.
Pitch,	3·2 to 4	3·6

After purification by the process described in the

* The pitch being wholly coked.
† The pitch not being coked.

article BENZOL these light oils yield (per 1000 gallons of tar):—

	Gallons.	
40 per cent. benzol...	3·44	= 6·84 at 90 per cent.
90 per cent. benzol,	5·31	
Solvent naphtha	4·18	
Last runnings,	1·2	
Total dead oils,	301·87	

R. F. SMITH.—Average English tar—1 ton of tar (sp. gr. 1·145) = 195·7 gallons, yields:—

	Gallons.		By volume. Per cent.
Ammonia water,	3	=	1·5
First runnings,	6	=	2·1
Light oils	$21\frac{1}{2}$	=	10·9
Creosote oils	66	=	33·7
	Cwts.		By weight.
Pitch,	$11\frac{3}{4}$	=	58·7

On rectification this yields—

	Gallons.		By volume. Per cent.
50 per cent. benzol.*	2·88	=	1·47
Solvent naphtha,	2·69	=	1·37
Burning naphtha,	3·51	=	1·79
Total creosote oils,	83 00	=	42·41

* Equal to 90 per cent. benzol, 1·60 gallons = 0·82 per cent.

E. KOPP states that, on an average (French?), coal tar yields the following amount—1 ton = 1000 kilogrammes = 900 litres, yields:—

	Litres.		By volume. Per cent.
Ammoniacal water,	13—14	=	about 1·5
Very light oils, mostly benzene,	29—30	=	" 3 2
Light oils, containing a little benzene, mostly suitable for solvent naphtha,	90—100	=	" 10·5
Creosote oils (distillation carried so far that hard pitch is left),	300—312	=	" 31·2
Do. of soft pitch left	190—200	=	" 21·7
			By weight.
Anthracene (pure, melting at 210° to 213°)	[Wholly coked?]		" $\frac{3}{4}$ to 1

The following two estimates are kindly furnished by practical distillers as being fair representations of the average results obtained from English coal tars:—

(A) WALTER SMITH obtained in 1869 the following numbers as the average yield of Lancashire tars. These vary considerably in composition, according to the quality used, the temperature employed in distillation, &c., some containing much napthalene, others but little. The quantity and quality of the carbolic acid obtained also vary much.

1000 gallons (about 5·3 tons, the tar having the sp. gr. 1·16) of tar yield—

	Gallons.		By Weight.
Ammoniacal liquor (containing 4 per cent. ammonia),	25	=	2 2
Light naphtha (first light oils),	28	=	2·2
Second light oils (sp. gr. not higher than that of water),	131	=	10·6
Creosote oils	87	=	7·6
Anthracene oils	191	=	16·9
	Tons		
Residual pitch,	$2\frac{1}{4}$	=	60·5
			100·0

On further rectification, &c., these distillates yield -

		Gallons.
Benzol, (at 90 per cent.)	about	6
Solvent naphtha	"	74
Carbolic acid,	"	$6\frac{1}{2}$
		Cwt.
Anthracene (at 30 per cent.),	"	$\frac{1}{2}$
Equal to pure anthracene,	"	0·15

(B) A. J. DICKINSON gives the following estimate as to the average yield from London tar. 1000 gallons produce—

	Gallons.		By Volume. per cent.
Naphtha containing 6 per cent. of benzol),	30	=	3
Ammoniacal water,	30	=	3
Anthracene (at 25 per cent),	10	=	1
Pitch,	650	=	65
Creosote, lubricating oils, carbolic acid, &c.,	280	=	28
	1000		100

The following table exhibits, side by side, the more detailed of these results. 1000 gallons of average tar yield—

	Source of Tar and Authority.				
	London. LETHEBY.	London. DICKINSON.	Lancashire. WATSON SMITH.	England. R. F. SMITH	France. (?) KOPP.
Gallons of ammoniacal liquor	24	30	25	15	15
" first light oils,	16	30	28	31	137
" second light oils,	12		131	109	
" creosote oils	288	280	87	337	217
" anthracene oils			191		95
Tons of pitch,	3 6	3·6	3·25	3·0	—
After rectification and purification—					
Gallons of benzol at 90 per cent, or lower percentaged benzol equivalent thereto	6·84	—	6	8·2	—
Gallons of naphtha,	5·38	—	74·	31·6	—
" creosote oils (total),	302·	—	—	424·	—
		Cwts.	Cwts.		Cwts.
Pure anthracene, or lower qualities equivalent thereto,	—	0·25	0·15	—	about 0 9 pitch coked(?)

VERSMANN's estimate of anthracene represents from 0·15 to 0·30 cwt. of *pure* anthracene per 1000 gallons of tar, if the pitch is not coked; and from 0·55 to 1·11 cwt. if wholly coked.

The "creosote oils," produced in somewhat large quantity in the distillation of ordinary British coal tar, constitute a material for which useful applications are still needed. The chief use to which they are at present put is for pickling or creosoting wood (railway sleepers, posts, timber, &c.), to prevent it from decay, or to preserve it from the ravages of insects; but the price commanded for this purpose is so low that many tar distillers simply use them, together with the naphthalene, as fuel underneath the stills,

&c. Attempts have been made to break them up by a sort of destructive distillation into illuminating gases and lighter volatile hydrocarbons, &c., the liquid oils being allowed to flow gently into retorts maintained at a red heat; a graphitoidal coke is formed in the retort, whilst gases of high illuminating quality and a light tar containing much benzene pass off, the latter being condensed by a worm tube or atmospheric condenser. This process is, however, not suitable for the tar distiller himself, but only for the gas-maker, who can utilize the permanent gases constituting the majority of the yield.

The following diagrams (Figs. 17 and 18) illustrate the process whereby these oils are used as fuel underneath the stills, steam boilers, &c:—The oils to be burnt are placed in a vessel, B, on the top of a boiler, A, through which receptacle the steam pipe,

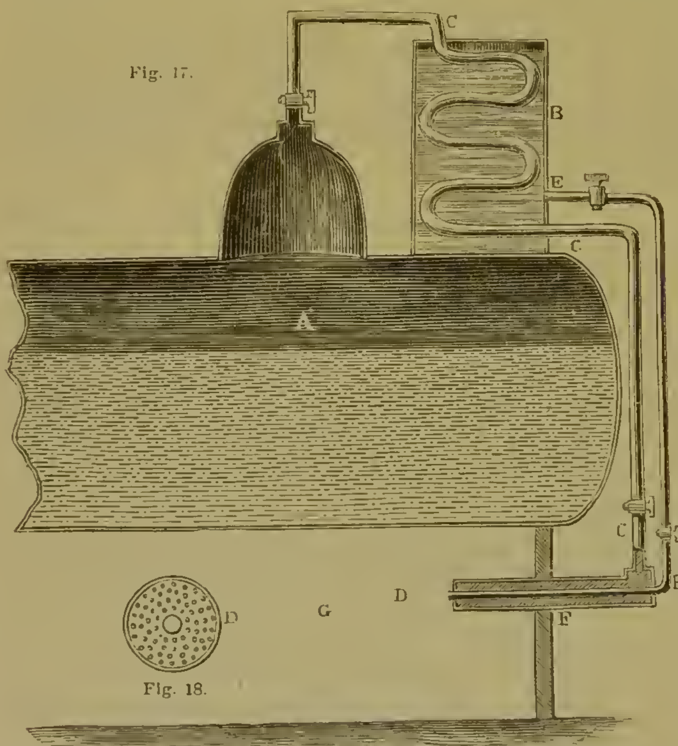


Fig. 17.

Fig. 18.

C C, passes, so as to keep the oils perfectly liquid, naphthalene and other solid hydrocarbons being dissolved in the hot fluid substances present. By means of taps the steam and the oils are allowed to pass through the pipes E E and C C, to an arrangement, F, of 2-inch iron piping, somewhat similar in construction to a Herapath blow-pipe; the oils are allowed to pass through the interior tube to a nozzle, D, where they are scattered in the form of spray by the jets of steam issuing through the perforations in the nozzle (Fig. 18). The furnace, G, being hot, ignites the issuing jet of spray, &c., and thus a powerful flame is kept up with but little consumption of fuel. The same arrangement may be applied to the still itself instead of a fire.

In the British colliery districts enormous quantities of coal are converted into coke for the purpose of iron smelting, fuel for locomotives, &c. Many attempts have been made to collect the products of distillation of coal formed during this process, but hitherto to little purpose. In order to produce a hard coke (such as is requisite for iron smelting) a high temperature in the coking oven is essential, and this can only be obtained by the admission of a certain amount of air into the oven, whereby the evolved vapours are burnt almost as fast as generated. Partly owing to the very high temperature at which the partially burnt products of distillation escape into the flues, and partly to the circumstance that any attempt at cooling and condensation of the vapours seriously interferes with the draught, and hence with the effectiveness of the coke oven, it results that the collection of tar products practically is either incompatible with the proper working of the ovens, or costs more than the products obtained are worth. Moreover, it by no means follows that the products of distillation of coal at a high temperature are the same as those formed at a lower temperature; experience shows that the quantity of tarry products is usually less the higher the temperature of distillation. It does not appear that attempts to obtain even ammonia from the volatile products of this kind of coke making have been commercially successful; partly, no doubt, owing to the actually smaller production of ammonia at the higher temperature, partly to the greater or less destruction of that which actually is formed during the partial combustion of the gases evolved in the coke oven itself, and partly from the mechanical and other difficulties in the way of its collection.

In the form of coke ovens now regarded as most effective, the gaseous products are so completely burnt in the ovens and flues that little, if any, visible smoke is emitted; one result of which is that a large proportion of the sulphur expelled from the coal during coking is emitted in the form of sulphurous acid, the destructive action of which (and the sulphuric acid thence resulting by natural oxidation) on the surrounding vegetation is most marked.

It is much to be regretted that the practical difficulties in the way of utilizing the enormous quantities of valuable products (amounting to hundreds of thousands of tons annually in England alone) thus wasted are so great. Were it rendered possible to obtain in saleable form the tarry products of the coal thus employed, and to utilize the vast stores of gaseous fuel thus generated, and immediately burnt to little or no purpose (beyond perhaps raising steam for the immediate purposes of the colliery, baking bricks, &c.), benefit would be conferred on the world at large, the pecuniary value of which would be very great.

Anthracene ($C_{14}H_{10}$). — This hydrocarbon was

first obtained by DUMAS and LAURENT in 1832 in an impure state, a circumstance which led to their attributing to the body a formula polymeric with that of naphthalene, viz., $C_{15}H_{12}$ (naphthalene being $C_{10}H_8$), and applying to it the term *Paranaphthalene;* the product investigated by these chemists melted at 180° C., and distilled at over 300° C. Subsequently LAURENT subjected the substance to further examination, and applied to it the name *Anthracene.* In 1857 FRITSCHE obtained from coal tar a hydrocarbon much resembling the anthracene of LAURENT, but melting at 210° to 212° C., and giving numbers in analysis agreeing with the formula $C_{14}H_{10}$. In 1862 ANDERSON showed that FRITSCHE's and LAURENT's products were identical, and obtained a number of anthracene derivations, notably anthraquinone. In 1866 LIMPRICHT showed by heating chlorobenzyl (C_7H_7Cl) and water to 180° C. anthracene was produced amongst other substances, and in the same year and the following one BERTHELOT found that anthracene is one of the bodies formed by the action of heat on various simpler hydrocarbons.

In 1868 GRÆBE and LIEBERMANN made the discovery from which dates the series of investigations from which the artificial production of madder colours has ultimately sprung, viz., that alizarin is really a derivative of the hydrocarbon anthracene, and is converted into anthracene when heated with finely divided zinc. The discovery of the converse reaction, or the conversion of anthracene into alizarin, soon followed, and thus an entirely new industry was created, viz., the manufacture from long decomposed vegetable matter of the dyestuffs up to that time only obtainable from the natural products of the madder tribe. As soon as a demand for anthracene was created improved processes for its extraction from coal tar were invented; and so rapidly has the new manufacture gained ground that madder cultivation is already seriously threatened.

Besides occurring in coal tar (and possibly in other kinds of tar), or in the products of its redistillation, anthracene can be formed synthetically in various ways; none of which, however, are as yet of practical value for the preparation of the substance. Thus—

(A.) Abstraction of the elements of hydrochloric acid and hydrogen from benzyl chloride (LIMPRICHT's reaction, *supra*):—

$$2C_7H_7Cl = 2HCl + H_2 + C_{14}H_{10}.$$

(B.) Action of heat on various more simple hydrocarbons, whereby hydrogen is evolved (BERTHELOT) thus:—Styrene (C_8H_8) + benzene (C_6H_6), when heated, give off hydrogen ($2H_2$) and yield anthracene ($C_{14}H_{10}$); two equivalents of toluene ($2C_7H_8$) give off six of hydrogen ($3H_2$) forming alizarin ($C_{14}H_{10}$); and two of benzene + one of ethylene ($2C_6H_6 + C_2H_4$), when heated in like manner, give off six of hydrogen ($3H_2$), anthracene ($C_{14}H_{10}$) being the resulting product.

(C.) Reducing action of nascent hydrogen on alizarin, anthraquinone, &c. GRÆBE, LIEBERMANN, &c.:—

$$\underset{\text{Alizarin.}}{C_{14}H_8O_4} + H_2 - O_4 = \underset{\text{Anthracene.}}{C_{14}H_{10}}.$$

$$\underset{\text{Anthraquinone.}}{C_{14}H_8O_2} + H_2 - O_2 = \underset{\text{Anthracene.}}{C_{14}H_{10}}.$$

(D.) Action of oxidizing agents on anthracene hydride and anthracene hexahydride, in each case hydrogen being withdrawn as water:—

$$\underset{\text{Anthracene hydride.}}{C_{14}H_{12}} - H_2 = \underset{\text{Anthracene.}}{C_{14}H_{10}}. \qquad \underset{\text{Anthracene hexahydride.}}{C_{14}H_{16}} - 3H_2 = \underset{\text{Anthracene.}}{C_{14}H_{10}}.$$

When pure, anthracene crystallizes in shining white scales or rhomboidal tables. When obtained by sublimation, it forms a very light mass of pearly white flakes. It melts at 213° C., and distils at close upon 360° C. Carbon disulphide dissolves 1·7 per cent. of anthracene, cold benzene 0·9 per cent., and alcohol somewhat less, 0·6 per cent. In water and aqueous alcohol anthracene is insoluble, and in petroleum light distillates it dissolves even less than in benzene. With picric acid it forms a characteristic compound crystallizing in ruby-red needles; and with an alcoholic or benzene solution of dinitro anthraquinone it forms reddish-violet rhomboidal scales. Nascent hydrogen (alcohol and sodium) unites with it, forming *anthracene hydride* ($C_{14}H_{12}$), which is again converted into anthracene by certain oxidizing agents, and forms *anthracene hexahydride* by the reducing action of hydriodic acid at 200° to 220° C. Chlorine attacks anthracene, forming *dichloranthracene* ($C_{14}H_8Cl_2$) and also *dichloranthracene tetrachloride* ($C_{14}H_8Cl_6$ or $C_{14}H_8Cl_2,Cl_4$). According to ANDERSON, *monochloranthracene* ($C_{14}H_9Cl$) and *anthracene dichloride* ($C_{14}H_{10}Cl_2$) also exist. *Trichloranthracene* ($C_{14}H_7Cl_3$) is got by the action of phosphorus pentachloride on anthraquinone. By the action of alkalies on dichloranthracene tetrachloride the elements of hydrochloric acid are removed, and *tetrachloranthracene* ($C_{14}H_6Cl_4$) is produced. Bromine forms similar compounds; thus *dibromanthracene* ($C_{14}H_8Br_2$) *tetrabromanthracene* ($C_{14}H_6Br_4$), *dibromanthracene tetrabromide* ($C_{14}H_8B_2.Br_4$), and *tribromanthracene* ($C_{14}H_7Br_3$) are known.

Oxidizing agents (*e.g.*, chromic acid), act energetically on anthracene and its substitution derivatives, forming *anthraquinone* or its derivatives, thus:—

$$\underset{\text{Anthracene.}}{2C_{14}H_{10}} + 3O_2 = 2H_2O + \underset{\text{Anthraquinone.}}{2C_{14}H_8O_2}$$

$$\underset{\text{Dibromanthracene.}}{C_{14}H_8Br_2} + O_2 = Br_2 + C_{14}H_8O_2$$

$$\underset{\text{Tribromanthracene.}}{C_{14}H_7Br_3} + O_2 = Br_2 + \underset{\text{Bromanthraquinone.}}{C_{14}H_7BrO_2}$$

Strong nitric acid forms anthraquinone and *dinitro anthraquinone*, $C_{14}H_6(NO_2)_2O_2$; in alcoholic solution, however, anthracene is converted by this agent into *mononitro anthracene*, $C_{14}H_9(NO_2)$; a *dinitro anthracene* ($C_{14}H_8(NO_2)_2$) also exists.

Concentrated sulphuric acid, especially the fuming acid, dissolves anthracene with the production of *anthracene mono-* and *di-sulphonic acids*, $C_{14}H_9(HSO_3)$, and $C_{14}H_8(HSO_3)_2$ respectively; these are readily converted by oxidizing agents into *anthraquinone mono-* and *di- sulphonic acids*, $C_{14}H_7O_2(HSO_3)$ and $C_{14}H_6O_2(HSO_3)_2$ respectively. Similarly, dichloran-

thracene and dibromanthracene form with fuming sulphuric acid *dichloranthracene sulphonic acid* $(C_{14}H_6Cl_2(HSO_3)_2$ and *dibromanthracene sulphonic acid* $(C_{14}H_6Br_2(HSO_3)_2$ respectively. Oxidizing agents readily convert these into *anthraquinone disulphonic acid*, hydrochloric (or hydrobromic) acid being disengaged.

By the action of nitric acid, or of strong sulphuric acid, on the product of the action of chlorine on anthracene, SCHÜTZENBERGER has obtained a red substance isomeric with anthraquinone, but differing from it in being insoluble in ammonia and caustic alkalies; when heated to 300° C. it becomes converted into ordinary yellow anthraquinone.

Of these and numerous other anthracene derivatives, a few only have a special commercial interest, from serving as intermediate products in the transformation of anthracene into madder colours.

VERSMANN gives the following table of solubility of anthracene in various liquids at 15° C.:—

	Per cent. Anthracene at 15°.	
	By volume.	By weight.
Alcohol of specific gravity, 0·800....	0·472	0·591
" " 0·825....	0·424	0·574
" " 0·830....	0 408	0·491
" " 0·835....	0·397	0·475
" " 0·840....	0·387	0·460
" " 0·850....	0·360	0·423
Ether,............................	0·858	1·175
Chloroform, ...	2·587	1·736
Carbon disulphide,.................	1·180	1·478
Glacial acetic acid,................	0·472	0·444
Benzol,...........................	1·470	1·661
Petroleum,........................	0·291	0·394

Manufacture of Anthracene.—The coal tar distiller sends into the market a rough product under the name of anthracene, which is simply obtained by collecting apart a certain portion of the coal tar distillate, which he terms anthracene oil. This is allowed to stand in tanks until the solid hydrocarbons have separated as completely as possible, and the deposited matter filtered off through sackcloth or stout canvas bags, the mother liquors being finally squeezed out by hydraulic pressure, or by a centrifugal machine, followed by hydraulic pressure. This crude product contains from 30 to 60 per cent. of actual anthracene. The mother liquors, which run off during the filtration and pressure, are collected and distilled somewhat after the fashion of the original coal tar, but on a smaller scale. The first portions of distillate are rejected, the higher portions worked up over again, just as the "anthracene oil" itself. The anthracene from the mother liquors contains a considerably smaller percentage of pure anthracene than the first crop of solid hydrocarbons. Frequently it is desirable to raise the quality of the product by hot pressure. The mass is steamed, and then subjected to hydraulic pressure while still hot. In this way naphthalene, and substances of low melting point, are much more thoroughly expressed than by simple cold pressure. This process of hot pressure may with advantage be applied to the cold-pressed anthracene obtained from the anthracene oil, a substance of higher percentage being thereby obtained. In England, however, it does not seem to be adopted, save for very inferior kinds. The crude anthracene thus obtained usually contains more or less of the following ingredients:—

A. — Hydrocarbons.—1. Solid at the ordinary temperature:—Anthracene, $C_{14}H_{10}$; naphthalene, $C_{10}H_8$; pyrene, $C_{16}H_{10}$: chrysene, $C_{18}H_{12}$; retene, $C_{18}H_{18}$; phenanthrene, $C_{14}H_{10}$; acenaphthene, $C_{12}H_{10}$. Benzerythrene, bitumene, &c. 2. Liquid hydrocarbons of high boiling point.

B. — Bodies not hydrocarbons:—Acridene, $C_{12}H_9N$, or $C_{24}H_{18}N_2$; carbazol, $C_{12}H_9N$.

Crude anthracene is valued by means of a rough method of proximate analysis, depending on the differences in the solubility in the various menstrua of pure anthracene, and the various products which accompany it, the latter being dissolved out and the former left. Unfortunately, it is impracticable by this means to obtain any accurate determination of the actual quantity of pure anthracene present, the results obtained with various solvents exhibiting great discrepancies; but inasmuch as tolerably accurate values can be obtained when some one process is rigidly adhered to, this mode of procedure can be used for technical purposes. It is, however, absolutely essential that every minute detail of the testing process should be previously agreed upon between buyer and seller. Thus, if the substance tested be oily, and be pressed before testing, a higher value is found, as the oily portion, if not removed, enables the solvent to take up more anthracene. The nature of the solvent (alcohol or carbon disulphide), the exact specific gravity of the alcohol (if the former be used), the quantity of solvent to be employed, and the exact mode of manipulation to be followed, must all be expressed in the contract.

The following description of the modes of testing commercial anthracene now employed is obligingly communicated by F. A. MANNING:—

Alcohol Test.—The sample is thoroughly mixed in a mortar, and 20 grammes are taken out and thoroughly stirred with 150 c.c. of alcohol, of the strength stated in the contract; the beaker is covered with a watch glass, gently heated to boiling, and allowed to cool to 60° Fahr., standing in water. After one hour's standing the liquor is decanted on to a filter, and the insoluble matter gradually washed with alcohol of the original strength at 60° Fahr., until the filtrate and washings measure 400 c.c. Should any visible sand be at the bottom of the beaker it is kept back; the insoluble part is then conveyed to a weighing glass and dried in a water bath at 212° Fahr. The weight of the residue, multiplied by 5, gives the percentage of so-called anthracene, and is the basis for payment.

The melting point is taken in a narrow glass tube, drawn out to a fine point; into this the anthracene is put to the depth of about 1 inch; it is then immersed, together with an accurate thermometer (or one the index errors of which are known by comparison with a standard thermometer), in melted paraffin, and the point at which the first drop runs

down is taken as the melting point. After complete liquefaction the lamp is removed from under the paraffin bath, and the temperature at which solidification takes place is noted; the mean between the former melting point and this temperature is then taken as the *mean melting point;* this should not be below 190° C.

Or, the quantity of substance melting at 190° C. (or some other fixed point) is determined. the specific gravity of the alcohol used being stipulated (usually 0·825), but not the quantity. A sample is treated as above, and the melting point determined. Should this be 190° C., nothing further is requisite; but if different, another test is made with a different quantity of alcohol (less if the melting point of the second specimen is to be above that of the first, more if *vice versa*). For instance—suppose No. 1 is boiled with 150 c.c. of alcohol and washed to 400 c.c., and gives a certain percentage, say 40, melting at 195° C.; No. 2 is boiled with 100 c.c. and washed to 300 c.c.; this gives a larger percentage (say 49) with necessarily a lower melting point, say 188° C. Then the quantity of substance melting at 190° C. is found by the proportion:—

$$195 - 188 : 49 - 40 :: 195 - 190 : x,$$

where x is the amount to be added to the lower percentage to give the percentage of substances melting at 190°. In the instance quoted

$$x = \frac{9 \times 5}{7} = 6{\cdot}4,$$

therefore the sample contains $40 \times 6{\cdot}4 = 46{\cdot}4$ of substance melting at 190° C.

Carbon Disulphide Test.—Ten grammes of the thoroughly mixed sample are shaken in a well-stoppered bottle with 30 c.c. of carbon disulphide, and allowed to stand for one hour at 60° Fahr. The insoluble matter is then thrown upon a filter, and the bottle washed out with 30 c.c. more of disulphide, any sand being kept back. After the liquid has run through the filter it is gently and quickly pressed between the fingers, and afterwards between blotting paper in a strong press. The insoluble matter is then transferred to a watch glass, dried for an hour at 100° C., and weighed; the weight multiplied by 10 gives the percentage. The mean melting point of a sample thus examined should not exceed 212° to 214° C.

The following tables illustrate the results of the tests of 400 different samples of crude anthracene by the alcohol test, and 250 by the carbon and disulphide test:—

ALCOHOL TEST.

About	12	per cent.	of the total number of samples contain, of so-called anthracene, *i.e.*, insoluble matter in alcohol, less than	20 per cent.
"	20	"	between	20 and 30 "
"	27	"	"	30 and 40 "
"	21	"	"	40 and 50 "
"	12	"	"	50 and 60 "
"	8	"	above	60 "

CARBON DISULPHIDE TEST.

About	6	per cent.	contain less than	10 per cent.
"	20	"	" between	10 to 20 "
"	39	"	" "	20 to 30 "
"	22	"	" "	30 to 40 "
"	8	"	" "	40 to 50 "
"	5	"	" above	50 "

As regards melting point, these tests give the following results:—

Melting Point.	Alcohol Test.	Carbon Disulphide Test.
	Per Cent.	Per Cent.
Below 190° C.	About 38	—
190° to 195°	48	—
195° to 200°	12	About 2
Above 200°	2	—
200° to 205°	—	23
205° to 210°	—	48
210° to 215°	—	23
215° to 218°	—	4

The relation between the results of these two sorts of test is by no means constant. VERSMANN gives the following table of comparative results obtained by the duplicate examination of thirty samples:—

Alcohol test. Per cent	Alcohol test. Melting point. Degs. C.	Carbon disulphide test. Per cent.	Carbon disulphide test. Melting point. Degs. C.
20	154	5	212
20	184	5	204
22	165	5	218
25	177	13	209
27	187	18	207
27	183	15	208
28	181	13	209
30	184	10	208
32	181	21	205
35	183	21	209
36	181	18	202
38	180	22	203
41	184	27	208
42	188	28	211
43	191	31	204
44	189	32	207
46	192	31	209
47	188	32	207
50	192	36	207
51	198	42	212
53	194	36	209
54	157	10	204
56	185	40	201
57	189	43	205
58	183	41	201
59	190	42	203
61	198	50	211
64	200	61	208
69	201	64	208
72·5	211	74	213

With low percentages the alchohol test gives a result four times as high as the carbon disulphide plan. With higher percentages the discrepancy becomes less and less, the alcohol test uniformly giving a higher value up to near 70 per cent., when the two processes nearly agree; the result of the alcohol test on the last case examined being actually lower than that of the carbon disulphide.

To remedy these inconveniences another test has been proposed by E. LUCK, and also by PAUL and COWNLEY, depending on the oxidation of anthracene to anthraquinone, and the solubility by alkaline solutions of the oxidation products of the hydrocarbons present other than anthracene. This may be worked

as follows:—Heat in a flask 1 gramme of anthracene together with 45 c.c. of glacial acetic acid till it quietly boils; add gradually, and at intervals of five to ten minutes, a solution of 10 grammes of chromic acid in 5 c.c. of glacial acetic acid and 5 of water. To prevent any loss of acetic acid during boiling, the flask is furnished with a condenser, which allows the acid constantly to flow back. About two hours' gentle boiling in most cases completes the decomposition, after which allow the flask to cool, add 150 c.c. of water, and allow it to stand for a couple of hours. Light yellow needles of anthraquinone then separate from the green liquid. Bring the whole on a filter, wash the crystalline residue first with water, then with a very dilute, hot solution of potash, until the liquid runs off perfectly colourless; and lastly, again with water, to remove traces of alkali. Now dry the filter in a water bath, and when perfectly dry detach the anthraquinone with a spatula, and weigh. This last direction is given in preference to weighing the residue and filter, because it has been found that the dilute chromic and acetic acid dissolve part of the filter paper, the original weight of which would be thereby altered.

The quantity of acetic acid and water used in this process dissolve 0·010 gramme of anthraquinone, = 1 per cent. on the weight taken; this amount must, therefore, be added to the percentage found. Hitherto this process has not come into use to any extent in the English trade, but it seems probable that it may eventually do so.

Refining.—Before anthracene of the ordinary English qualities can be used for colour-making it must be purified. The tar distillers usually prefer to manufacture very rough products. The colour maker prefers to purchase a refined article rather than to have the trouble of refining the crude article himself. An intermediate class of manufacturers, viz., anthracene refiners, has therefore sprung up. The processes employed by them, as far as they are known, appear to consist of cold and hot pressing, and washing with various solvents, notably the distillates from petroleum, boiling at towards 90° C. (not above 100°, on account of the greater solubility of anthracene in such distillates, and the increased difficulty in removing the last traces of the washing liquid used). By these means the majority of the impurities present are washed out with but little waste of anthracene, and a partially purified anthracene of 75 or 80 per cent. is obtained. Sometimes the petroleum distillate is used at a boiling temperature. There seems to be no reason why this part of the refining process at least should not be carried out by the tar distiller, who can work up mother liquors and bye products much more readily than an anthracene refiner, to whom everything that is not anthracene is a waste material.

For the final purification SCHULER recommends distillation, or rather sublimation, a current of air being driven into the retort. Tolerably pure anthracene is driven over, and condenses in yellowish snow-like flakes, a form which is peculiarly adapted to oxidation. To complete the purification the sublimed powder is boiled with freshly distilled petroleum, boiling at 120° to 150° C., and filtered and well pressed. When chemical purity is requisite, the product is crystallized two or three times from alcohol, dried, sublimed very slowly, and the sublimate washed with ether, which removes the last traces of an adhering yellowish product; this may also be removed by dissolving in hot benzol and bleaching by sunlight.

Anthraquinone ($C_{14}H_8O_2$), *and its Derivatives.*—Anthraquinone itself (the *anthracenuse* of LAURENT and the *oxanthracene* of ANDERSON) is most conveniently obtained by acting on anthracene dissolved in glacial acetic acid with chromic acid. On a manufacturing scale sulphuric acid and potassium dichromate are employed; or nitric acid, either alone or along with acetic, may be used. The oxidized mass is washed and dried and then sublimed: when pure it melts at 273° C.

Anthraquinone varies in colour somewhat, according to the mode of preparation adopted. It is usually more or less yellow or reddish yellow, but can be obtained almost white by solution in sulphuric acid, and precipitation of the solution by water. Nitric acid of spec. grav. 1·4 dissolves it unchanged; but a mixture of nitric and sulphuric acids forms *dinitro anthraquinone* $(C_{14}H_6(NO_2)O_2)$. The long-continued action of dilute acid also forms a dinitro anthraquinone; so that when heated for a long time with sulphuric acid it forms *mono-* and *di- anthraquinone-sulphonic acids*, respectively $C_{14}H_7(HSO_3)O_2$, and $C_{14}H_6(HSO_3)_2O_2$. When fused for a long time with caustic potash, oxygen is taken up and alizarin is formed; a complete decomposition is, however, produced in this case, benzoic acid being formed, and at a certain stage of the operation a non-crystalline citron-yellow product, probably *anthraquinhydrone*, $C_{28}H_{16}O_4$.

Zinc dust (containing zinc hydrate), when heated with anthraquinone, converts it into anthracene, as does also a mixture of zinc and hydrochloric acid. Bromine acts on anthraquinone in sealed tubes at 160° C., forming dibromanthraquinone, identical with that produced from tetrabromanthracene by oxidizing agents. Chlorine acts in a similar manner in forming dichloranthraquinone.

Alizarin ($C_{14}H_8O_4$).—The two most important anthraquinone derivatives, alizarin and purpurin, are respectively a di- and tri- hydroxylated anthracene.

Alizarin acts as a weak dibasic acid; thus its calcium salt is indicated by the formula $C_{14}H_6O_2(CaO_2)$: analogous barium, aluminium, and other salts are known. By the action of ethyl iodides on sodium alizarate, *diethyl alizarate*, $C_{14}H_6O_2(OC_2H_5)_2$, is produced, whilst monomethyl alizarin, $C_{14}H_6O_2(OH)(OCH_3)$, and monoethyl alizarin, $C_{14}H_6O_2(OH)(OC_2H_5)$, are obtainable by the action on alizarin of a mixture of caustic potash, alcohol, and methyl or ethyl iodide (SCHUNCK). Benzoyl chloride acts on alizarin, forming *dibenzoyl* alizarin, $C_{14}H_6O_2(O.C_7H_5O)_2$ and acetic anhydride gives rise to diacetyl alizarin, $C_{14}H_6O_2(O.C_2H_3O)_2$. Fuming sulphuric acid forms *alizarin monosulphonic acid*, $C_{14}H_5(HSO_3)O_2(OH)$; on